

**/COMPUTER PROGRAM FOR SIZING AND ANALYZING  
FIXED SHADING DEVICES  
(SHADE)/**

by

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**B. Arch., Bombay University, India, 1985**

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**A Master's Thesis**

**submitted in partial fulfillment of the  
requirements for the degree**

**MASTER OF ARCHITECTURE**

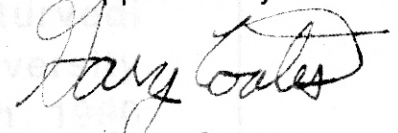
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**Department of Architecture  
College of Architecture and Design**

**KANSAS STATE UNIVERSITY  
Manhattan, Kansas**

**1990**

Approved by :



**Prof. Gary Coates**

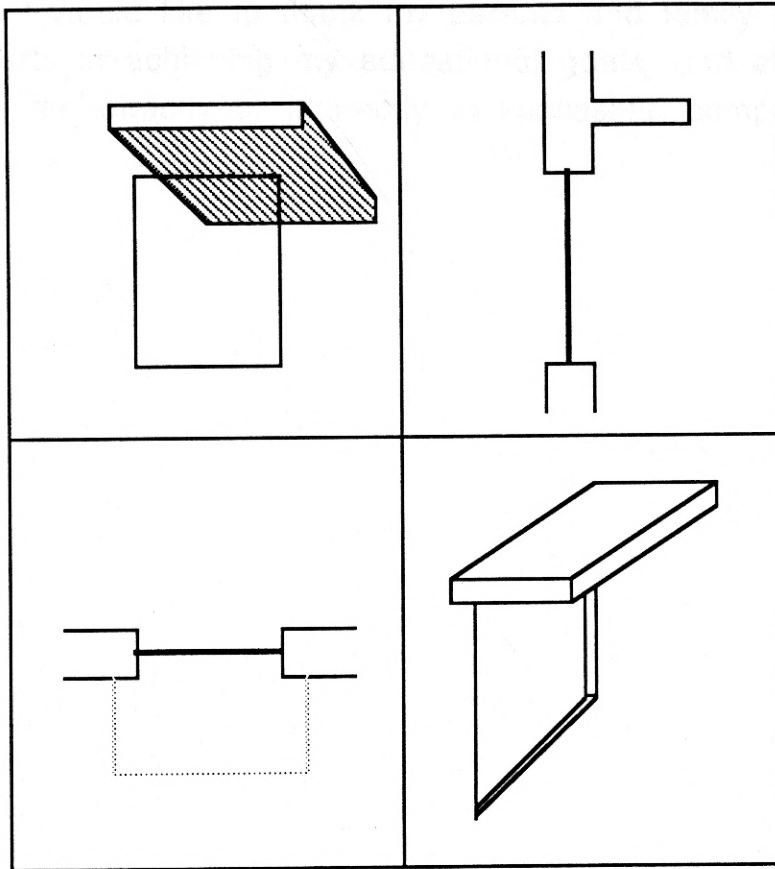
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# Computer Program for Sizing and Analyzing Fixed SHAding DEvices

## SHADE



Vinod Chaturvedi  
Kansas State University  
March 1990

# Acknowledgements

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## Abstract



# Preface

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Passive solar design has now become a significant part of the process of architectural design. In order to design efficient passive solar building it is necessary to provide appropriately sized shading devices that allow sun to strike the window when it is needed and block the sun when it is too hot for comfort. By enhancing the designer's ability to design shading devices, the computer program SHADE contributes to the development of the field of passive solar design.

SHADE allows architects working in the preliminary design phase to size and evaluate the performance of fixed horizontal overhangs and/or vertical wing walls. It is also a useful tool for lay persons and students of architecture who are interested in learning more about Environmental Systems in Architecture. Now, with SHADE it is easier not only to size the fixed shading devices but also to evaluate the shading performance of these devices at any time of year, without using the cumbersome process of constructing sun path diagrams or making models to be tested under simulated solar conditions.

A basic knowledge of solar design is still required to use this program - such as having an ability to visualize the solar positions at different times of day and for different seasons. The 'beginner' is strongly advised to read "Designing with the LOF Sun Angle Calculator" distributed by Libbey-Owens-Ford Company, Toledo, Ohio, 1975 before operating SHADE.

Phase-I of SHADE is developed to allow the user to size and locate fixed horizontal overhangs. The limitation for sizing horizontal overhangs is that they only can be sized correctly and practically for windows facing within 10 degrees east or west of due south.

The vertical wing walls can be sized in Phase-II for all window orientations. However, it will work most accurately for windows

facing + or - 30 degrees of due south. For all other window orientations, the sizing would still be accurate, but due to certain assumptions regarding the appropriateness and location of wing walls explained later in the text (pg. 20), the output may not be reliable.

The edge effect of the overhang can be addressed by suitably sizing the overhang extension beyond the left or right edge of the window in Phase-III.

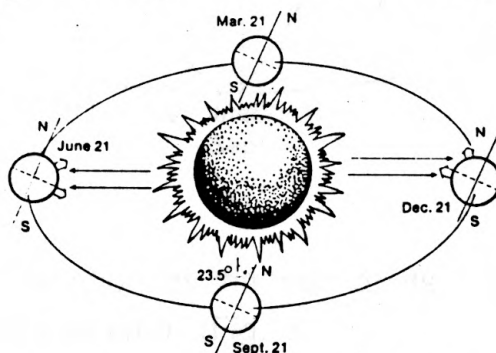
The strongest and perhaps the most useful feature of SHADE is the shadow pattern simulation of shading devices in Phase-IV. The performance of a horizontal overhang or a combination of horizontal overhang and vertical wing walls can be evaluated by viewing the shadow pattern for the design under consideration at one hour intervals for the entire year, even at different window orientations. The size of overhang or wing walls can be the one derived through the program in Phase-I and II or the user can choose to evaluate any other design of his or her choice. The only limitation is that, in order to be able to view a shadow pattern for a combination of horizontal overhang and vertical wing walls, the sizes of both the projections will have to be the same. This requirement of the program is the result of the need to simplify the shadow patterns.

A user can study various permutations and combinations of fixed shading device designs and carefully evaluate them all before selecting the one (or ones) that are most appropriate for the design under consideration. To facilitate the use of SHADE generated results outside the computer work station, a hard copy of any desired graphics or text output can be easily printed at the stroke of a key anytime during the entire execution of the program.

# Introduction

---

<sup>1</sup>A south facing window in a passive solar building designed to gather as much sun as possible in winter, while reducing the winter space heating demands may also lead to overheating the interior if left exposed during the summer months. Controlling this cycle throughout the year is an important aspect of energy conserving passive solar design. A horizontal overhang that is properly located above the window is one simple way to shade the collector during summer months while leaving it unshaded during winter.



**Fig. 1** This and fig. 2, 3 & 6 are reproduced from "Sizing Fixed Overhangs for Solar Collectors", a handout distributed by the Technical Energy Information Services of the KSU Cooperative Extension Service, 1983.

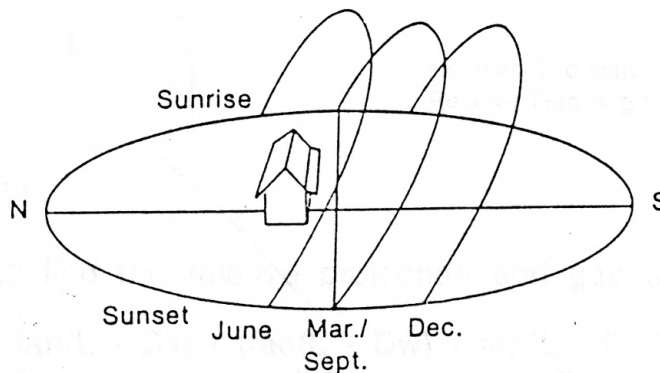
Latitude, window size and orientation all affect the design of an effective sun shading device. The earth's axis is not perpendicular but is tilted at a constant angle of  $23^{\circ} 27'$  to the plane in which it orbits the sun. Because of this fact, at one point in the orbit, i.e. during winter, the axis tilts away from the sun, resulting in the sun appearing low in the sky. At the opposite point, half a year later during summer, the axis is tilted toward the sun, causing the sun to appear higher in the sky (Fig. 1). Thus a building located between the

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<sup>1</sup> The northern hemisphere is used in all the explanations in introduction. But since the sun motion is symmetrical about the equator, whatever happens in northern hemisphere will be repeated in southern hemisphere six months later.

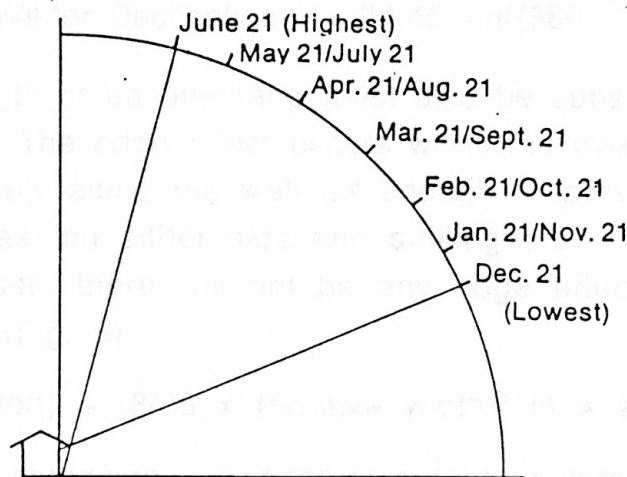
tropics will actually have sunlight on the north side in June and the south side in December.

The time of year is equally important. The figure below illustrates the seasonal variation in sun path. In summer, the sun rises and sets north of the east-west line while in winter it rises and sets south of that line.



**Fig. 2**

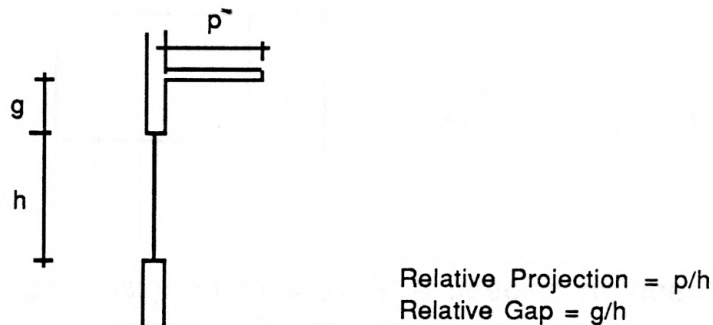
Also, note how the elevation of the sun at its highest point, or solar noon, changes with the season. (Fig. 3)



**Fig. 3**

For the window to be fully sunlit in the winter, there must be a gap between it and the overhang. The gap is the space between the bottom of the overhang and the top of the window. The overhang projection and gap are usually expressed as ratios with respect to the window height. The relative projection is the required projection

divided by the window height. Similarly, the required gap divided by the window height gives the relative gap. (Fig. 4)



**Fig. 4 :** Section

The equation to find the relative projection and gap are as follows<sup>1</sup>:

$$\text{Relative gap} = \tan(L - D_s) / (\tan(L - D_w) - \tan(L - D_s))$$

$$\text{Relative Projection} = 1 / (\cot(L - D_s) - \cot(L - D_w))$$

Where,  $N_s$  = (Number of desired shade days in summer)  $\times$  1/2

$N_w$  = (Number of desired sun days in winter)  $\times$  1/2

$L$  = Latitude

$D_s$  = Summer Declination =  $23.45 \sin((360 / 365)(N_s + 456))$

$D_w$  = Winter Declination =  $23.45 \sin((360 / 365)(N_w + 639))$

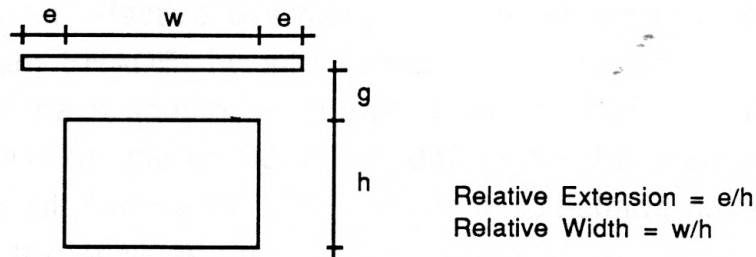
The correct length of an overhang must also be considered to avoid the edge effect. The edge effect occurs when the overhang does not extend horizontally along the wall far enough to prevent the sun from slipping past on either side and striking the window. For all practical purposes, there will not be any edge effect if the following relation is true (Fig. 5) :

$$(\text{relative extension}) + [3/25 \times (\text{relative width})] \text{ is } > 2.7$$

Where, relative extension = horizontal overhang extension along the wall beyond the window / window height

relative width = window width / window height

<sup>1</sup> From "Sizing Fixed Overhangs for Solar Collectors", a handout by Energy Extension Center, Kansas State University.

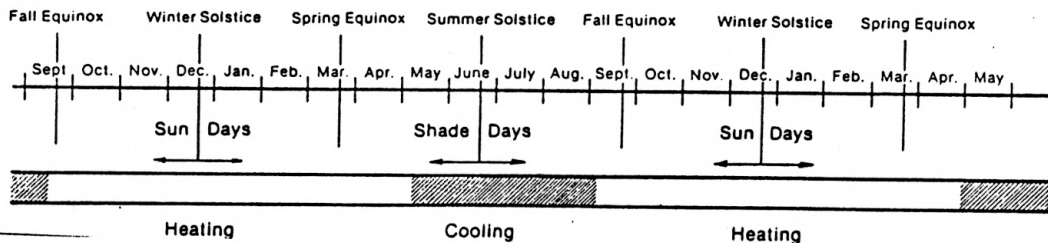


**Fig. 5** : Elevation

An overhang can be designed to provide a specific number of days of full sun striking the window in winter and complete shade in summer. The rest of the time the window will be partly shaded and partly exposed.

Ideally, windows should be shaded during the entire cooling season (i.e. summer) and sunlit during the entire heating season (i.e. winter). But this usually is not practical unless moveable devices are built. In general, the more full-sun or full-shade days desired, the larger the overhang has to be.

Another problem is that while the days of full shade and full sun are symmetrical around the summer and winter solstices, the maximum heating and cooling loads normally occur 30 to 45 days after the respective solstices. (Fig. 6). This symmetry of the shading about the solar cycle rather than the heating and cooling cycle means, for instance, that a window shaded during the summer will likely be shaded during the latter part of winter, too.



**Fig. 6**



Thus, to design an effective overhang for a given window using the computer program SHADE the site latitude, and preferred number of shade and sunlit days should be known (Refer to "List of User-Defined Variables" on pages 30-32, to determine the number of full shade days and full sun days). The number of full-shade days does not have to be the same as the full sun-days.

#### PHASE I. INPUT DATA

This segment of the program asks only for windows facing 0 or 90 degrees of true south. For all other window orientations, the sun is too low in the sky for any overhang to be effective. It will have to be unusually large, which in turn may not be practical.

Input: Height and width of window under investigation, the site latitude, desired number of full shade days and full sun days. (Refer to "List of User-Defined Variables" on pages 30-32, to determine the number of full shade days and full sun days.)

Output: The size of overhang projection and the year for the top of the window.

#### PHASE II. SIZE OF OVERHANG

For most of the windows facing between east or west of due south, an overhang alone will not be enough to shade the window entirely and effectively especially during the hottest period of the year. An appropriately sized wall on one or both sides of the window depending on window orientation may be designed to reduce this problem.

# Program Overview

---

SHADE is developed to size and locate fixed shading devices, such as horizontal overhangs in Phase-I and vertical wing walls in Phase-II, for any window at any latitude. The edge effect of the overhang can be addressed by suitably sizing the overhang extension beyond the left or right edge of the window in Phase-III. The performance of a shading device can be evaluated for the entire year, at different window orientations, in Phase-IV. The description of each phase is as follows :

## **PHASE-I.** SIZING OVERHANG

This segment of the program works only for windows facing + or - 10 degrees of due south. For all other window orientations, the sun is so low in the sky that for any overhang to be effective, it will have to be unusually large, which in turn may not be practical.

**Input** : Height and width of window under investigation, the site latitude, desired number of full shade days and full sun days. (Refer to "List of User-Defined Variables" on pages 30-32, to determine the number of full shade days and full sun days.)

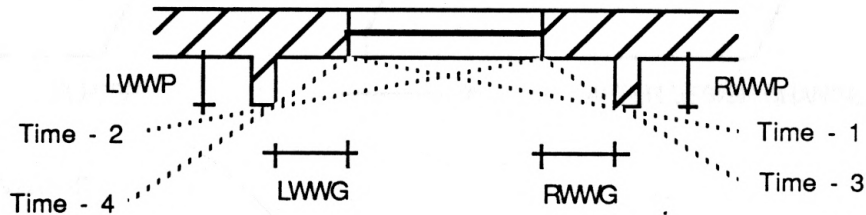
**Output** : The size of overhang projection and the gap from the top of the window.

## **PHASE-II.** SIZING WING WALL

For most of the windows facing between east or west of due south, an overhang alone on top of the window may not be enough to shade the window entirely and effectively especially during the hottest period of the day. An appropriately sized wing wall on one or both sides of the window (depending on window orientation) may be designed to counter this problem.



**Input** : Height and width of window, site latitude, orientation of window, desired month, day, and beginning hour (Time -1) and ending hour (Time - 2) between which 100% shade is required; and desired month, day, and beginning hour (Time - 3) and ending hour (Time - 4) between which 100% sun is required.



**Fig. 7** : Plan

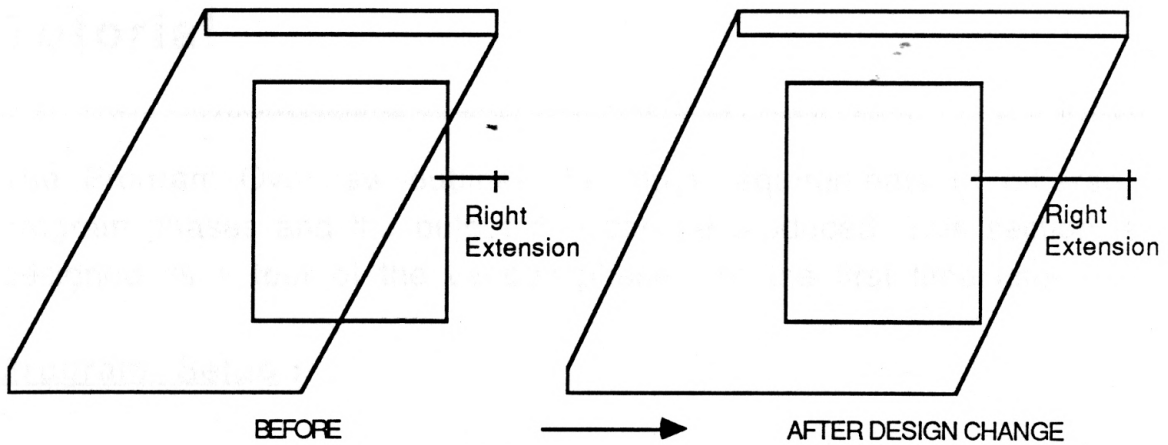
**Output** : The size of the right and left wing wall projections and their respective gaps from the edge of the window.

### **PHASE-III. OVERHANG EXTENSION**

An alternative to placing wing walls on one or both sides of the window is to have an overhang extending beyond the sides of window to such a length that it will nullify the edge effect. (See explanation in Introduction).

**Input** : Size of window, site latitude, orientation of window, desired month, day of month, and beginning and ending hours of day for 100% shade.

**Output** : The length of the overhang extension on one or both sides of the window. (fig. 8)



**Fig. 8 :** Elevation

#### **PHASE-IV. SHADOW PATTERN**

There are two parts to this section. Part One is the shadow pattern simulation for a window with only a horizontal overhang. Part two is for a window with both a horizontal overhang and a wing wall on one or both sides of the window.

**Input** : height and width of window, orientation of window, desired month of year, and day of month for viewing shadow casting pattern.

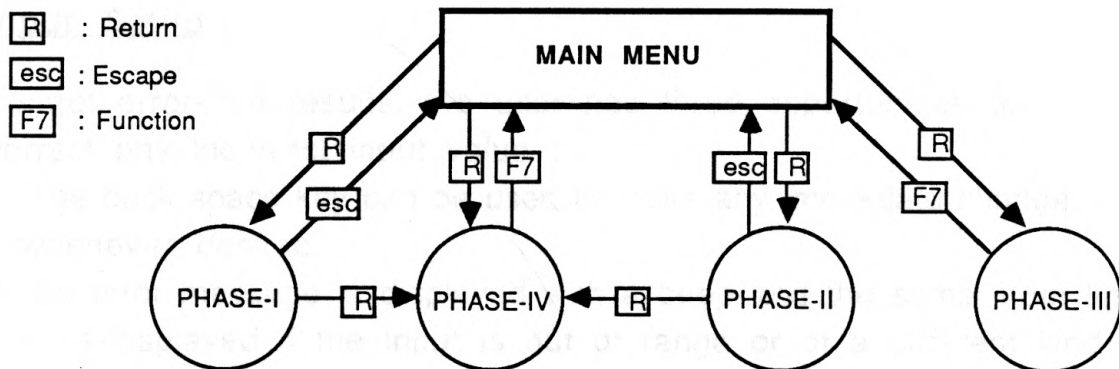
**Output** : Shadow pattern simulation for the entire year at one hour intervals, beginning from the first hour after sunrise to an hour before sunset for each day. Also, the percentage area of the window in sun and shade is shown for each hour.

# Tutorial

---

The Program Overview outlines the input requirements of different program phases and the output that can be produced. This section is designed as a tour of the various phases for the first time user.

## Program Setup :



**Fig. 9 :** The boxes indicate the key to be pressed to get into or out of various phases.

The operation of the program is fairly simple. The program is presented in a phased manner, and most of the steps follow a definite sequence. Upon choosing any phase from the Main Menu, there is first a brief explanation of various input requirements relevant to that phase. After reading through the text the user may proceed with that phase by pressing any key on the keyboard (except ESC). It is possible to return to the Main Menu by pressing "**ESC**".

For some of the steps in this program, the user is advised to follow a certain sequence. For example, a user may not get into the shadow pattern simulation phase of program if the overhang or wing wall sizes are not defined. This sizing may be done first by entering the appropriate phase. It is also possible to use some pre-determined size for the horizontal overhang or wing walls. In such case, the

user is not required to enter the sizing phase of overhang or wing walls.

### **Default Setup :**

All the inputs, including the main menu, have a default value which is defined in the first run of the program. All subsequent changes of this value by the user become the default value for the next run of the program until the user exits SHADE.

### **Input Setup :**

To get error-free results, the user has three opportunities to correct any incorrect input value :

1. The back space key can be used to make any immediate change whenever desired.
2. An error message is displayed with a beep and the same input line is re-displayed if the input is out of range or of a different kind (e.g. a real number in place of an integer), or if there are unrelated characters in the numeric input.
3. After completion of all related inputs in one section, a message is displayed to confirm all of the input values. The user can, at this stage, change one or all input values or proceed to confirm.

### **Scaling :**

The program is designed to automatically scale the graphic output according to the size of the window, or the resultant size of overhang and wing walls. The default scaling factor is 10 raster units to 1 foot.

### **Unit :**

The program uses feet and inches in decimal format as its input/output parameter.

## EXAMPLE

---

In this example the following operations will be demonstrated -

1. Size the overhang in Phase-I for a 3' x 5' south facing window situated in Manhattan, KS at 39° north latitude. (For error checking purpose, use 40°)
2. Use the same window above to size the wing walls in Phase-II.
3. Use the same window to determine the length of the overhang extension in Phase-III with its resulting shadow pattern.
4. View the shadow pattern for the above window in Phase-IV -
  - A. With only the horizontal overhang sized in Phase-I.
  - B. With a combination of horizontal overhang and vertical wing walls sized in Phase-II.

The first thing that is displayed on the screen after entering SHADE is the title page followed by Main Menu.

---

Select an Option

(Item)	(Explanation Field)
P1 PHASE-I	Sizing Overhang
P2 PHASE-II	Sizing Wing Wall
P3 PHASE-III	Sizing Overhang Extension
P4 PHASE-IV	Shadow Pattern
P5 EXIT	From SHADE to DOS

---

**Fig. 10** : Main Menu

The items in the Main Menu are scrolled through by using the "Up" and "Dn" arrow keys. When either of the keys is pressed, the selected item is highlighted and the explanation field is displayed. Press <Return> to select the highlighted item. An item from the menu list can also be selected by pressing the letter "P" and the number associated with that menu item followed by pressing <Return>. The default item is always PHASE-I.

Select PHASE-I and press <Return>

## **PHASE-I :**

A brief note about this phase and its Input specifications is displayed.

Press any key to continue

Now, begins the input section of Phase-I. Enter the following values at their respective prompts :

SITE LATITUDE : 40

WINDOW WIDTH : 3

WINDOW HEIGHT : 5

NO. OF DESIRED SHADE DAYS IN SUMMER : 60

NO. OF DESIRED SUN DAYS IN WINTER : 90

After the 'END INPUT' signal, the prompt reads -

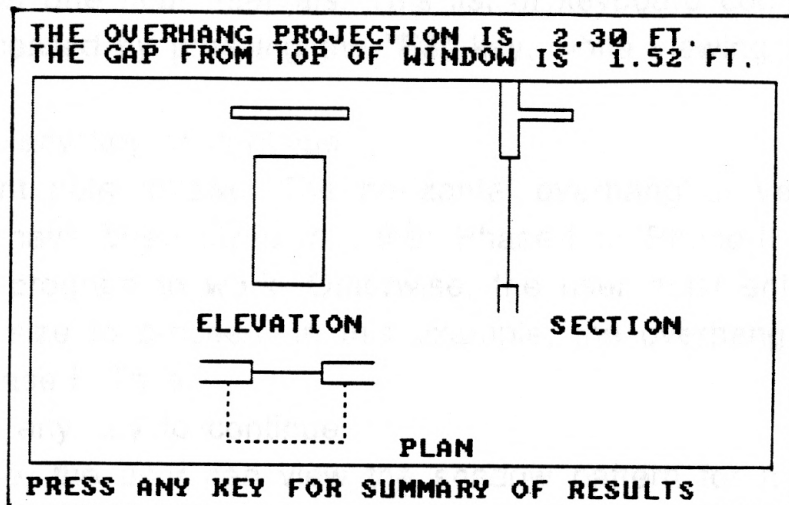
DO YOU WANT TO CHANGE ANYTHING, Y OR N :

Check to see at this point that all the values entered are numerically correct. Then -

Enter <N> for no change and

Press <Return>

The resultant output is the plan, elevation, and section of the window as shown below (Fig.11). The size of overhang projection and gap is also displayed -



**Fig. 11**

- 
- Note :** 1. The overhang extension on both sides of the window is assumed to be 1 foot for simplicity.
2. See Appendix-D for the size of overhang obtained manually using the graph developed by Energy Extension Center, Kansas State University.
- 

Press any key for summary of results

The summary is given as shown below :

Latitude : 40  
Window width : 3  
Window height : 5  
Number of full shade days in summer : 60  
Number of full sun days in winter : 90  
Overhang projection : 2.30 ft.  
Gap from top of window : 1.52 ft.

To take a look at the shadow pattern for the overhang we just sized

Press any key to continue

#### **PHASE-IV :**

This phase begins with a brief explanation, and lists the keyboard commands to be used for viewing the shadow pattern for any day of the month at one hour intervals. This list of keyboard commands can also be accessed by pressing the "F3" key, while viewing the shadow pattern.

Press any key to continue

An important note follows. The horizontal overhang or vertical wing walls must have been sized in either Phase-I or Phase-II for this part of the program to work. Otherwise, the user must enter a pre-determined size to proceed. In this example, the overhang was just sized in Phase-I. Thus -

Press any key to continue

At this stage, the user can view the shadow pattern for a combination of overhang and wing walls (choice 2), but we are interested in viewing the shadow pattern only for the overhang at this time, so -

Enter <1> at the MAKE SELECTION prompt and  
Press <Return>



Another important note follows including a display of the current set of input values. The user can use any other pre-determined size of overhang at this stage, but we will use the size of the overhang just determined in Phase-I, so -

Enter <1> at the MAKE SELECTION prompt and  
Press <Return>

Now we are in the input section of this phase. Enter the following values at their respective prompts -

WINDOW ORIENTATION : 0  
MONTH OF YEAR FOR SHADOW CASTING : 6  
DAY OF MONTH FOR SHADOW CASTING : 21

- 
- Note :** 1. The shadow pattern always begins with the first hour after sunrise and ends at the hour before sunset for the day chosen. This eliminates the need for entering time of day.
2. The Solar Position Charts listing altitude and azimuth angles for 0 to 64 degrees north latitudes at an interval of 8 degrees are included in Appendix-B for reference.
3. All the times used here are actual 'solar time'. Solar time is measured relative to local solar noon - the instant when the sun is exactly south (or north) of the observer. Local solar noon is usually different than local standard time which can be as much as one hour. But this can be ignored, because the length of the shaded time is the same.

---

After the 'END INPUT' signal -

Enter <N> for no change and  
Press <Return>

Now, the user can see the shadow pattern for the window under investigation, with its overhang as sized in Phase-I. Since, the first hour after sunrise on June 21 for 40 degrees north latitude is 5 a.m. the values that are displayed on the screen are -

TIME OF DAY : 5  
DATE : 6/21  
ORIENTATION : 0.00  
ALTITUDE : 4  
AZIMUTH : 117



Any time of the day when the sun is not shining directly onto the wall which houses the window, the following messages are displayed :

NO SHADOW ON WALL (if the sun is still beyond the wall face after the sunrise hour)

NO SHADOW ON WALL TILL SUNSET (if the sun has gone beyond the wall face)

The other self explanatory messages are -

NO SUNRISE YET

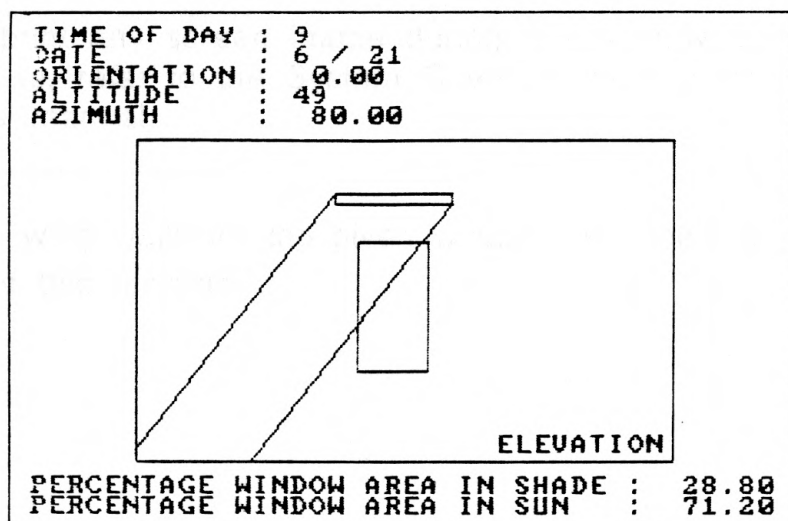
SUNRISE HOUR - GO TO NEXT HOUR

SUNSET HOUR - TRY THE HOUR BEFORE

THE SUN IS DOWN

In this example, the sunrise hour for June 21 is 5.00 a.m.. So the first output that is displayed on the screen shows 'NO SHADOW ON WALL'. This is because the azimuth is 117 degrees east of due south, while the window is facing due south. Anytime during the day the azimuth is greater than 90 degrees there will be no shadow on the wall face. The first shadow pattern that appears on the screen is for 9.00 a.m. when the azimuth is 80 degrees and the altitude is 49 degrees (Fig. 12). The corresponding percentages of window area in shade is 28.80% and the area in sun is 71.20%.

Similarly, the message 'NO SHADOW ON WALL TILL SUNSET' is displayed at 16 hours (4.00 p.m.), because the azimuth now is 91 degrees west of due south.



**Fig. 12**

- 
- Note :** 1. For this program all azimuth angles east of due south are considered positive, while those west of due south are negative.
2. See Appendix-A for the Heliodon test photographs to compare the shadow patterns for the same size of window at same latitude as used in this example.
- 

The user is in complete control during this shadow simulation phase of the program. Use the following keys as indicated to analyze the effect of the overhang on the window -

<--	: TO PREVIOUS HOUR
-->	: TO NEXT HOUR
ARROW UP	: TO NEXT MONTH
ARROW DN	: TO PREVIOUS MONTH
HOME	: TO FIRST HOUR AFTER SUNRISE
END	: TO HOUR BEFORE SUNSET
PG UP	: TO DECEMBER 21
PG DN	: TO JUNE 21
+	: ADD 5 DEG. TO ORIENTATION
-	: SUBTRACT 5 DEG. FROM ORIENTATION
F3	: HELP
F7	: TO EXIT

The "F3" key functions as a help feature. When it is depressed it lists all the above commands for easy reference.

Pressing the "F7" key will return the user to the Main Menu.

---

**Note :** To print any screen image during this shadow simulation phase, refer to the System Overview section (pp. 28-29) of this manual.

---

To size the wing walls for the given window, we need to go to Phase-II of this program.

## **PHASE-II :**

---

**Note :** For any window facing south to have wing walls, logically, it must also have an overhang. Therefore, it is advisable to go to Phase-I before entering this phase.

---

Use the arrow key to go one line down in the menu list. The explanation field for PHASE-II is now highlighted.

Press <Return>

A brief note about this phase and its input requirements will be displayed on the screen. This phase of the program will work most accurately for windows facing within 30 degrees east or west of due south. For all other window orientations it would still be accurate, but the output is based on certain assumptions regarding the appropriateness and location of wing wall as explained on next page.

Press any key to continue

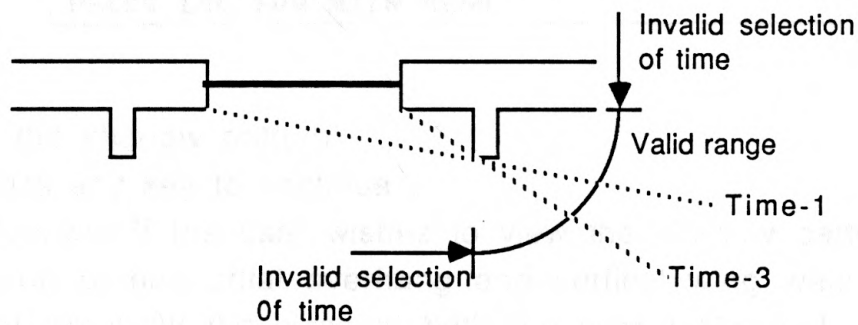
Another important note follows. This phase of program works only for the window values used in Phase-I. So the user must go to Phase-I if he or she has not already done so. Alternatively, it is possible to proceed without going to Phase-I, if the current values listed here are acceptable. For this example, the current values were already defined while in Phase-I. Thus -

Press any key to continue

Now you are in the input section. Enter the following values at their respective prompts :

WINDOW ORIENTATION : 0  
MONTH OF YEAR FOR 100% SHADE : 5  
DAY OF MONTH FOR 100% SHADE : 21  
BEGINNING HOUR OF DAY FOR 100% SHADE : 9  
ENDING HOUR OF DAY FOR 100% SHADE : 15  
MONTH OF YEAR FOR 100% SUN : 11  
DAY OF MONTH FOR 100% SUN : 15  
BEGINNING HOUR OF DAY FOR 100% SUN : 9  
ENDING HOUR OF DAY FOR 100% SUN : 15

**Note :** 1. If the user is sizing wing walls for a window facing between  $30^{\circ}$  and  $170^{\circ}$  of due south then the prompt to enter the beginning hours for 100% shade (time-1) and for 100% sun (time-3) are not displayed. It is assumed that for these orientations the wing wall to the right side of window (as displayed on the screen) will not be appropriate. Similarly, for a window facing between  $190^{\circ}$  and  $330^{\circ}$  of due south, the prompts to enter the ending hours for 100% shade (time-2) and for 100% sun (time-4) are not displayed. It is assumed that the wing wall to the left of window is not appropriate.



**Fig. 13 :** Plan indicating the valid selection of time when the azimuth is within the range shown.

2. If a user, for a beginning hour or for an ending hour enters a time when actually the sun is behind the wall face or is at a position subtending an obtuse angle with respect to the wall face, then an error message 'INVALID SELECTION OF TIME' is displayed (Fig. 13). The user in such cases is required to change this time suitably in the next cycle of input prompts by entering <Y> after the 'END INPUT' signal.

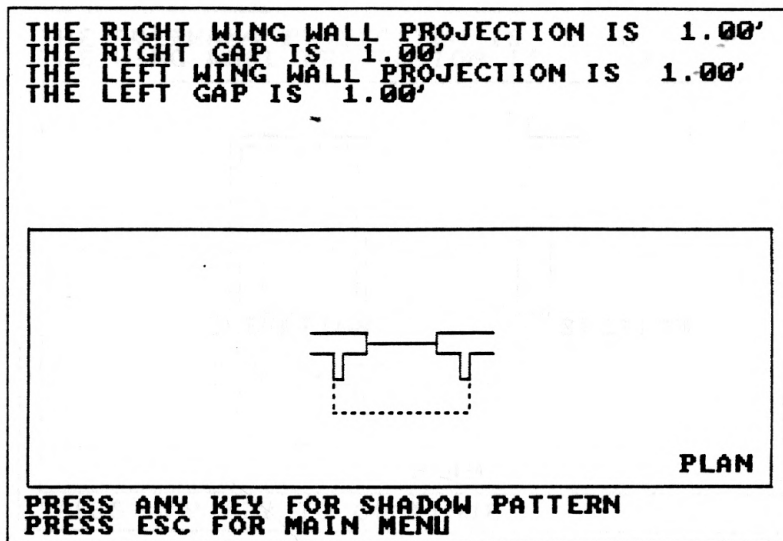
---

After the 'END INPUT' signal -

press <N> for no change, if the values entered are numerically correct.

Press <Return>

The output displayed is the plan of window with the appropriate wing walls as shown below. The numeric wing wall projections and gaps are also shown



**Fig. 14**

To view the shadow pattern -

Press any key to continue

A note follows. If the user wishes to view the shadow pattern for a combination of horizontal overhang and vertical wing walls, then for reason of simplicity the sizes of both the wing walls and the overhang projections will have to be the same.

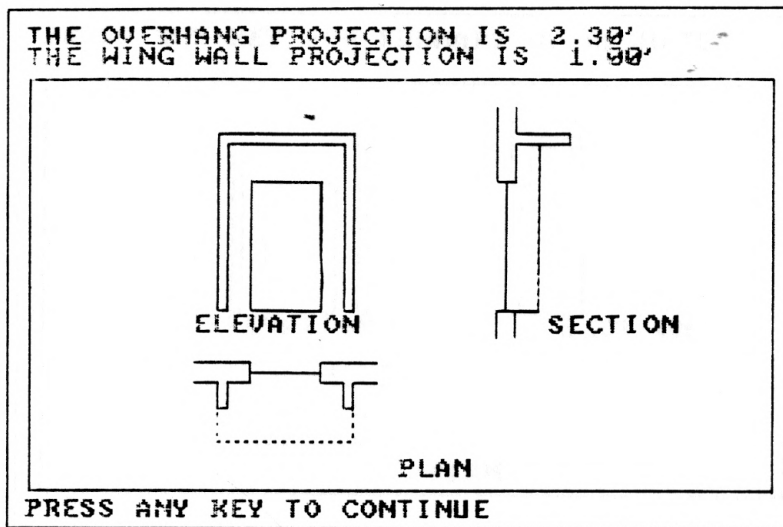
Press any key to continue

At this stage, if the right and left wing wall projections sized earlier are different, then the user has the following three options to maintain equal sizes for both wing walls for uniformity in design

1. Select the smaller of the two dimensions
2. Select the average of the two dimensions
3. Select the larger of the two dimensions

In this example, since both wing walls are of the same size, these options are not displayed.

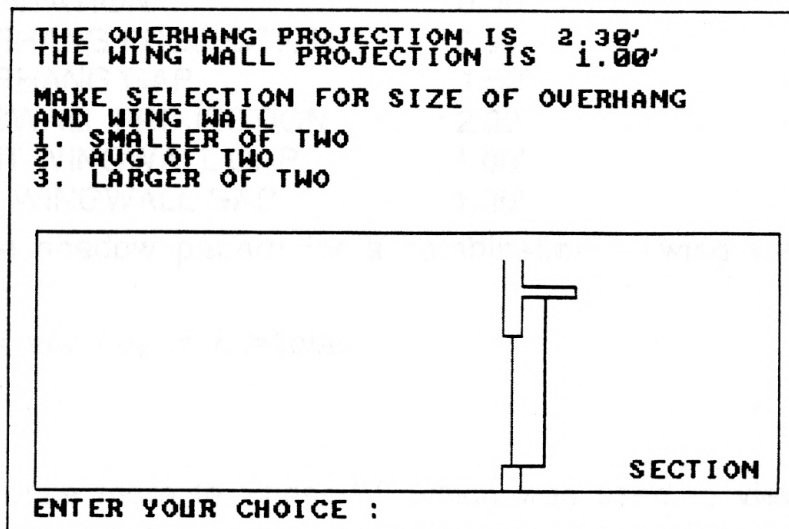
Instead, this time the screen shows the plan, elevation, and section of the given window as shown below with appropriate overhang projection and its gap (from Phase-I), as well as the wing wall projection and its gap.



**Fig. 15**

Press any key to continue

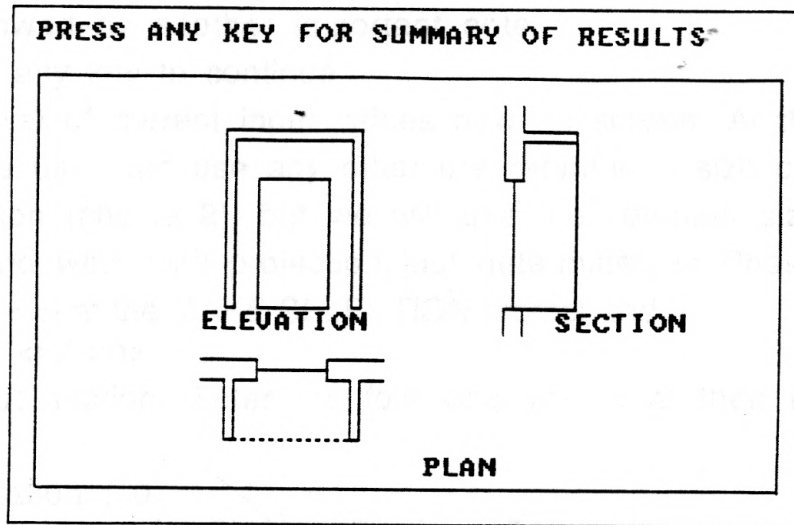
The screen shows the section of window with appropriate overhang and wingwall projections. Again, the user has the three options listed above to override the calculated dimensions.



**Fig. 16**

Enter <3>, the larger of two dimensions, for this example and press <Return>

The graphic screen this time shows the plan, elevation, and section as before, but with final projections and gaps of overhang and wing wall combination.



**Fig.17**

Press any key for a summary of the results

The final output is given as below :

SIZE OF WINDOW	: 3.00' x 5.00'
LATITUDE	: 40
ORIENTATION	: 0.00
OVERHANG PROJECTION	: 2.30'
OVERHANG GAP	: 1.52'
WINGWALL PROJECTION	: 2.30'
RIGHT WINGWALL GAP	: 1.00'
LEFT WINGWALL GAP	: 1.00'

To view the shadow pattern for a combination of wing walls and overhang -

Press any key to continue

-----  
This leads once more to Phase-IV, which was used to view shadow pattern for the overhang sized in Phase-I. The procedure to follow is similar to the one used before.

Press any key to continue

After reading the important note -

Press any key to continue

Since, the shadow pattern for a combination of horizontal overhang and vertical wing wall is to be viewed -

Enter <2> at the MAKE SELECTION prompt, and  
Press <Return>



This is followed by another important note.

Press any key to continue

There is a list of current input values now on screen. At this moment, the user can use any other pre-determined size of wing wall projection (choice 2), but we will use the common size of overhang and wing wall projection just determined in Phase-II. So -

Enter <1> at the MAKE SELECTION prompt and  
press <return>

This is input section. Enter the following values at their respective prompts -

Orientation : 0

Month of Year for Shadow Casting : 5

Day of Month for Shadow Casting : 21

Again, at the END INPUT signal -

Enter <N> for no change, and

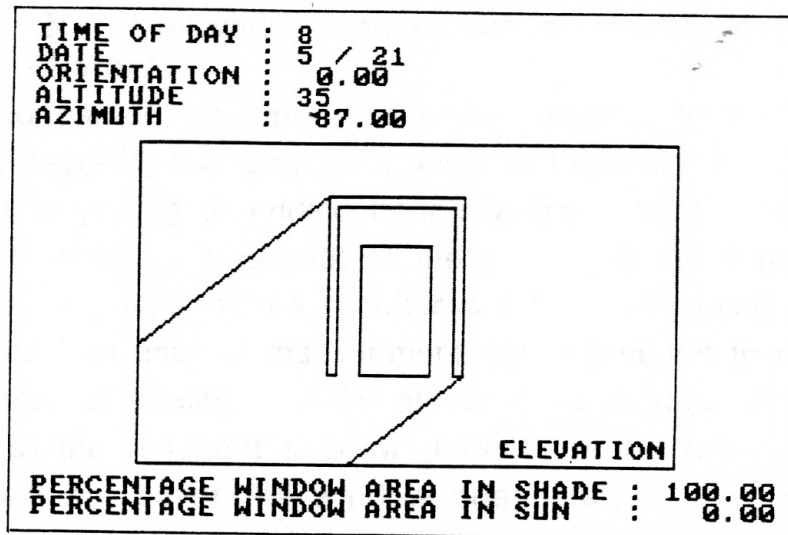
Press <Return>

The first output displayed at 5.00 a.m. on June 21 for 40 degrees north latitude on the screen shows 'NO SHADOW ON WALL', because, as explained earlier, the azimuth at the first hour after sunrise is 115 degrees east of south which is greater than the wall face angle of 90 degrees. Use right arrow key to move forward until you see the first shadow pattern on the screen. This is for 8.00 a.m., at which time the azimuth is 87 degrees and the altitude is 35 degrees (Fig. 16). The window at this stage is 100% in shade.

Use the same keys explained before to evaluate the shadow performance for different times of the day, for different months, or for different orientations.

Pressing the "F7" key will return the user to Main Menu.





**Fig. 18**

### **PHASE-III :**

Select Phase-III from the Main Menu. The explanation field will be highlighted.

Press <Return>

This phase begins with a brief explanation and its input/output requirements. Since in this phase the user can size the overhang extension and view its resultant shadow pattern simultaneously, the procedure to proceed is the same as used in Phase-IV.

Press any key to continue

An important note follows. The size of the overhang must be defined by means of Phase-I for Phase-III of SHADE to work. Otherwise, the program uses the current values listed on the screen to proceed. For this example, the overhang has already been sized. Thus -

Press any key to continue

Now, you are in the input section of this phase. Enter the following values at their respective prompts -

ORIENTATION : 0

MONTH OF YEAR FOR 100% SHADE : 5

DAY OF MONTH FOR SHADOW CASTING : 21

BEGINNING HOUR OF DAY FOR 100% SHADE : 10

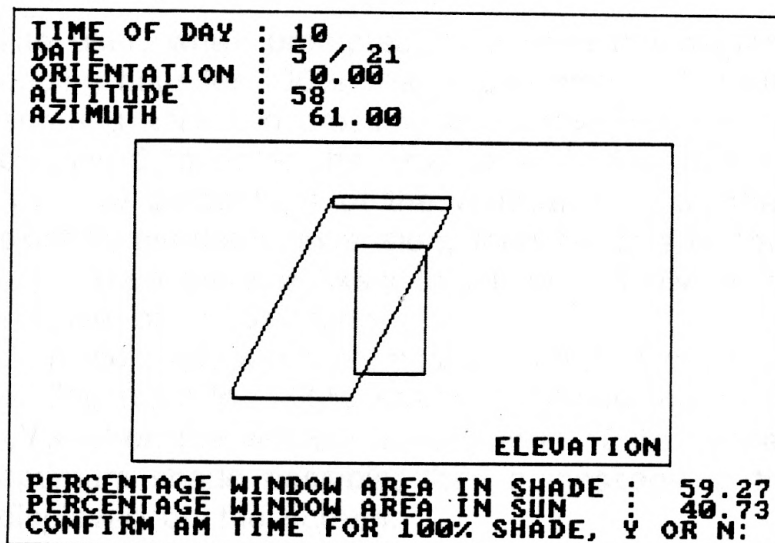
ENDING HOUR OF DAY FOR 100% SHADE : 14

After the 'END INPUT' signal -

Enter <N>, if all values entered are numerically correct, and  
Press <Return>

As explained earlier, the operation of this section of the program is similar to Phase-IV; the only difference is that, when the user reaches the beginning or ending hour shadow pattern entered in the input section, there is a prompt at the bottom of the screen asking the user that the time before or after which 100% shade is desired be confirmed. The user at that moment has the option to change the beginning hour or ending hour (whatever is applicable), if he or she foresees that the resultant shadow pattern for the new overhang extension will not cover the window adequately.

In this example, while viewing the shadow pattern for May 21, upon reaching the shadow pattern for 10 a.m., there will be a prompt at the bottom of the screen to confirm the beginning or ending hour for 100% shade. (Fig.19)

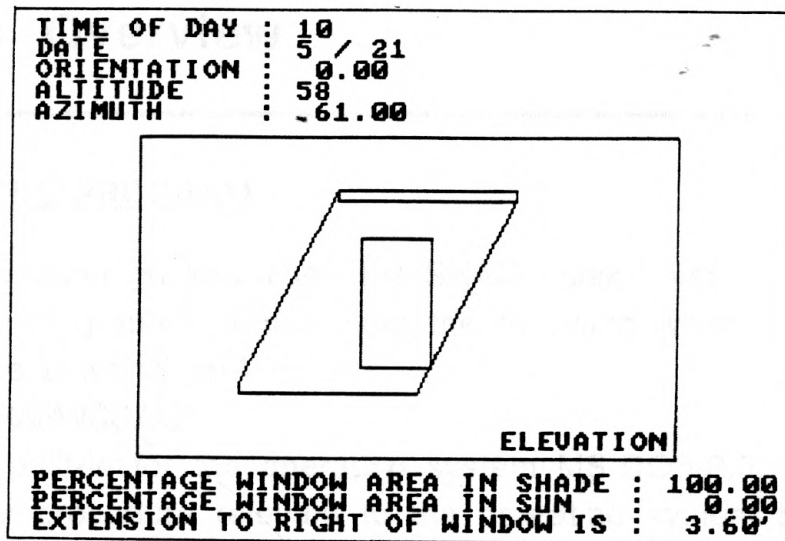


**Fig. 19**

At this point -

Enter <Y> to confirm, and  
Press <Return>

The overhang extension to the right side of window is adjusted accordingly to be 3.60 ft. long. (Fig. 20)



**Fig. 20**

Similarly, upon reaching the 14 hour (2 p.m.) shadow pattern, confirm the time for 100% shade, and the left extension is also adjusted to be 3.60 ft.

- Note :** 1. The user, when prompted to confirm the beginning or the ending hour for 100% shade, can change the time by entering <N> and pressing <Return>. Now, the user will be prompted to enter the new time. If the user is satisfied with the percentage of the window area in shade for the existing overhang extension, then he or she can enter a time when there is likely to be no shadow on the wall (e.g. sunrise or sunset time).
2. If the user, when prompted to confirm the beginning or the ending hour for 100% shade, confirms the time by entering <Y> when the window already is in 100% shade or in the optimum shade possible, then a message to that effect is displayed on the screen.

Use the same keyboard commands as in Phase-IV to view the shadow pattern for the entire year, or press "F7" to exit.

Pressing function "F7" key will return the user to the Main Menu.

Use the "down" arrow key to go to the bottom of Main Menu to exit from program SHADE and return to the operating system.

This ends the tutorial section.

# System Overview

---

## **LOADING THE PROGRAM :**

Turn the computer on and insert the SHADE disk. First, to enable the printer to print graphic output, type the following while in DOS mode, before entering SHADE -

C > GRAPHICS.COM

This file is built-in for the operating system MS-DOS/2.0. Use any other similar procedure relevant to the operating system being used. Now, change the drive from C to A (or B whichever is appropriate) and type SHADE -

C > A:

A > SHADE

or, if the program has been loaded on the hard drive, then just type SHADE -

C > SHADE

In a short time the title page will appear. Pressing any key then leads to the Main Menu. Now the user takes control of the program as explained in the Program Overview (pp. 8-10) and Tutorial sections (pp. 11-27) of this reference manual.

## **HARDWARE REQUIREMENTS :**

SHADE will run on IBM PCs or compatibles with one disk drive and 75K of memory. It is recommended that a color monitor be used. Also, a graphics printer is necessary if hard copy is desired. The use of a hard disk drive with math co-processor will speed up the operations considerably.

## **PRINTING :**

A user can get a hard copy at any stage during the entire run of SHADE. Press <prt sc> while pressing the shift key on the keyboard, when the printer is ready. This command is known as 'screen dump',

which when called will print everything on the current screen onto an attached printer without saving the contents of screen. A dot matrix printer with graphic capabilities such as Epson Fx 100, Brother HR 35, Alps ALQ 200 is necessary to get such a hard copy. The important thing to note is that, the in-built graphics file must be enabled before entering SHADE. Refer "Loading the Program" section on previous page for the procedure.

# List of User-Defined Variables

---

1. Latitude (L) : Integer :  
Indicates the location of the site in northern or southern hemisphere. The value ranges from  $0^{\circ}$  to  $90^{\circ}$  for northern latitudes, and  $0^{\circ}$  to  $-90^{\circ}$  for southern latitudes. (Refer U.S. and world maps included in Appendix-C to locate latitudes for a given place.)
2. Height of Window (H) : Positive non-zero real :  
The height of the window in feet from sill level.
3. Width of Window (W) : Positive non-zero real :  
The width of the window in feet.
4. Number of Desired Shade Days in Summer (Ns) : Positive non-zero integer : Indicates the total number of days in summer when the window needs to be in 100% shade from sun; half of this number is before summer solstice (June 21) and half after.
5. Number of Desired Sun Days in Winter (Nw) : Positive non-zero integer : Indicates the total number of days in winter when the window needs to be in 100% sunlight; half of this number is before winter solstice (December 21) and half after.

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**Note :** The desired number of full shade and sun days are to be determined by analyzing the regional and site modified climate of the building under consideration. Any period during the year that the temperature goes over the comfort zone<sup>1</sup>, would result in a 100% shade requirement. When the temperature drops below the comfort zone, there would be a 100% sun requirement during that period of year. Buildings which generate a significant amount of internal heat due to lights, people and equipments (an internally loaded building)

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<sup>1</sup> It is the dry bulb temperature range within which human beings will feel comfortable, when combined with the effect of relative humidity, wind speed, metabolic and clothing level.



will require more days of full shade than a building without such internal loads (a skin loaded building). See "Sun, Wind and Light" by G. Z. Brown (pp. 33 - 35), MEEB - Seventh edition, by B. Stein et al. (pp. 34 - 49), and "Upsidedown" by G. Z. Brown et al. (pp. 3-21 to 3-32) for a discussion of how to determine when shade is needed for any given building.

---

6. Overhang Projection (P) : Positive non-zero real :  
Indicates the perpendicular length of overhang projection, in feet, from the face of the wall. Although this value is achieved through the program, it can also be chosen by the user to simulate the shading pattern for any pre-determined overhang. (See fig. 4, pg. 5)
7. Overhang Gap (G) : Positive non-zero real :  
Indicates, in feet, the position of the bottom of the overhang from the top of window. Although this value can also be determined through the program, it can also be chosen by the user to simulate the shading pattern for any pre-determined overhang. (See fig. 4, pg. 5)
8. Overhang Extension to Right of Window (ER) : Positive non-zero real : Indicates the length of overhang, in feet, beyond the right edge of window. (See fig. 5, pg. 6)
9. Overhang Extension to Left of Window (EL) : Positive non-zero real : Indicates the length of overhang, in feet, beyond the left edge of the window. (See fig. 5, pg. 6)
10. Right Wing Wall Projection (RWWP) : Positive non-zero real :  
Indicates, in feet, the perpendicular projection of the right wing wall from the face of the wall. Normally derived through the program, it can also be chosen by the user who desires to see the shadow pattern simulation of a pre-determined wing wall. (See fig. 7, pg. 9)
11. Left Wing Wall Projection : (LWWP) : Positive non-zero real :  
Indicates, in feet, the perpendicular projection of the left wing

wall from the face of the wall. Normally derived through the program, it can also be chosen by the user who desires to see the shadow pattern simulation of a pre-determined user-defined wing wall. (See fig. 7, pg. 9)

12. Right Wing Wall Gap : (RWWG) : Positive non-zero real :  
Indicates, in feet, the clear gap from the right edge of the window to the right wing wall. Normally derived through the program, it can also be chosen by the user who desires to see the shadow pattern simulation of pre-determined user-defined wing wall. (See fig. 7, pg. 9)
13. Left Wing Wall Gap : (LWWG) : Positive non-zero real :  
Indicates, in feet, the clear gap between the left edge of the window and the left wing wall. Normally derived through the program, it can be chosen by the user who desires to see the shadow pattern simulation of a pre-determined user-defined wing wall. (See fig. 7, pg. 9)
14. Orientation (ORIENT) : Positive real :  
Indicates, in degrees, the orientation of the window due east of true south. The value ranges from  $0^{\circ}$  to  $360^{\circ}$ .
15. Beginning Hour (AM\_TIME) : Positive non-zero integer :  
Indicates the beginning hour of the day after which 100% shade or sun is required. The range varies from 1 to 24.
16. Ending Hour (PM\_TIME) : Positive non-zero integer :  
Indicates the ending hour of the day before which 100% shade or sun is required. The range varies from 1 to 24.
17. Month of Year (mm) : Positive non-zero integer :  
Indicates the month of year when shadow pattern is to be viewed. The range is from 1 to 12.
18. Day of Month (dd) : Positive non-zero integer :  
Indicates the day of the month when the shadow pattern is to be viewed. The range is from 1 to 31.



# Future Improvements and Additions

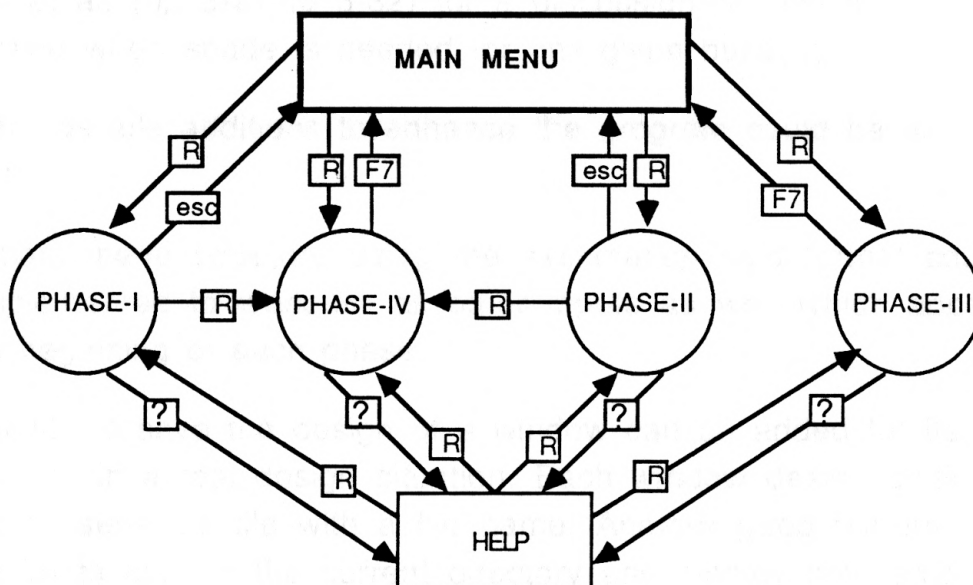
---

Writing a computer program is a continuing process. No program is ever complete and there is always scope for future additions, alterations or updates. The two suggested future additions for SHADE are as follows :

## 1. HELP MENU

An active help menu can be added to be accessed at every change of screen image. The help screen shall display :

- Brief information about all four phases.
- All user-defined variables with brief explanation.
- All major user-operated keyboard commands.
- All hardware directives like save, delete, retrieve, print and their use.



**Fig. 21**

## **2. BALANCE POINT TEMPERATURE CALCULATION**

To get a more accurate and realistic estimate of the number of desired shade days in summer and sun days in winter, the balance point temperature can be found based on the internal heat gain analysis of the building under investigation. This analysis shall include heat generated - in terms of <sup>1</sup>Btu<sup>S</sup> per hour - by people, lighting, machines (if any), and any other heat generating source. This total heat gain when plotted against the <sup>2</sup>skin/volume ratio of the building gives the resulting balance point temperature. Any day the outdoor temperature goes over this balance point temperature, the building needs to be cooled; subsequently requiring 100% shade. On the other hand, if the outdoor temperature goes over the balance point temperature, the building needs to be heated; subsequently requiring 100% direct sunlight. See "Sun, Wind and Light" by G. Z. Brown (pp. 33 to 35), "Mechanical and Electrical Equipment for Buildings" - Seventh edition by B. Stein et al. (pp. 34 to 49), and "Upsidedown" by G. Z. Brown et al. (pp 3-21 to 3-32) for a discussion of how to determine when shade is needed for any given building.

The other possible additions to enhance the program could be as follows :

3. The main menu structure using the explanation field format could be implemented to work for all other inputs as well which appear at the beginning of each phase.
4. The ability to save the design of a window can be added for its usefulness in a real design situation. Each window design could be saved as separate file with a file name. Another good feature would be to look at the current directory and display the names of

---

<sup>1</sup> British thermal unit.

<sup>2</sup> The total surface area in square feet of four outside faces of the building + area of one roof divided by total cubic feet of volume enclosed by the skin.

all legal databases for selection for reading or writing the computer data files.

5. For the program to be of much use in the analysis stage of design, it would have to be able to print out tables summarizing the performance of the window designed. A table with the percentages of shading and non-shading area for a particular period of time (a day) would allow the user to compute heat gain as part of overall energy analysis of the building. These reports could be made available as a formatted display either on the screen or in a file. An alternative file format (fields separated by commas, with alphanumeric information in double quotes) would make the data available to LOTUS 1-2-3 or a database management system for further analysis.

6. There could also be an option to print the summary of the window design to a file or to a printer. Window designs could be named and dated with the current date.

## Conclusion

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"...Analysis methods for solar design allow the designer or researcher to investigate and, in many cases, predict the thermal performance of a particular building or system. These tools provide an alternative to constructing costly working models and often allow an extended forecast of system behavior, under varying loads and inputs, which may not be easily attainable through a physical representation..."

(From "Microcomputer Methods for Solar Design and Analysis", A brochure developed by the Building Applications and Regulatory Support Branch of Solar Energy Research Institute.)

The author while being a teaching assistant for the course Environmental Systems in Architecture I (taught in the Department of Architecture at Kansas State University by Professor Gary Coates) felt the need to write a computer program which would speed up the task of sizing window shading devices by eliminating the use of sun charts and graphically finding the resultant size of the overhang projection and gap. The need was further felt when it was found that the personnel at the Energy Extension Center at Kansas State University were using a graphic chart developed by them to size the overhang, which was somewhat time consuming and not an attractive way to present the results to a client. The need is further compounded when it is realized that, it is hard to evaluate the shading performance of the resultant overhang over the period of the entire year unless a model is built and tested in a heliodon or by the use of other such time consuming methods. This is where SHADE takes the driver's seat and lets the user view the shadow pattern for the sized overhang and wing walls over a period of one year, and at any orientation, in no almost time. The results can also be printed using a graphics printer any time during the entire run of program.

Research was conducted to find out if there was any comparable software available in the market, before undertaking this thesis. No

such program was identified. It is hoped that SHADE will prove useful to passive solar designers.

The SHADE program is written using Turbo Pascal version 3.0 which supports a very limited use of graphic operations with little knowledge of computer programming language. It is not perfect nor is it methodically structured in its code. In other words, it could have probably been lot smaller and faster in its run, if it had been optimized using precise methods. The program has been tested to run successfully by some of the users (the user response has been included in the Appendix-F) and compared with results of an extensive model test inside the Kansas State University, Department of Architecture heliodon. The results in the form of photographs are included in the Appendix-A. Also, included in the Appendix-B are the solar position charts for various latitudes. It is possible that SHADE may still have some bugs in it, which went undetected. If such an error is encountered, the user is advised to reboot the system and start with a different set of values.

In conclusion, it can be affirmed that SHADE will save a considerable amount of time for the tasks that it is designed to address, if used correctly and with care.

## Appendix

## A. Heliodon Test Results

The photographs of the test inside heliodon at Department of Architecture, Kansas state University for following data are included here.

Latitude = 40 degrees north

Window width = 3 ft.

window height = 5 ft.

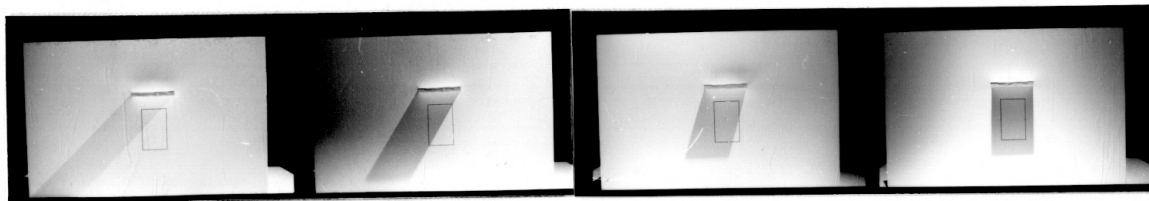
Overhang projection = 2.30 ft.

Gap from top of window = 1.52 ft.

Orientation = 0 degrees (facing due south)



June 21 -->



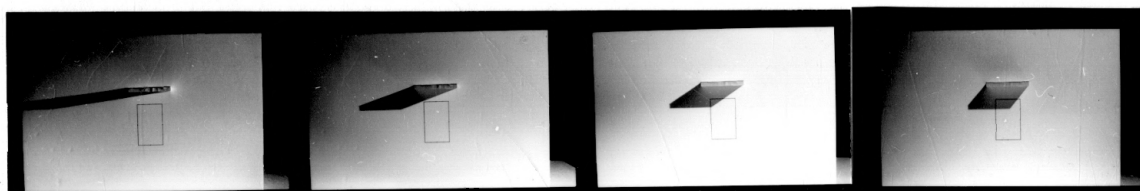
9 a.m.

10 a.m.

11 a.m.

12 p.m.

March/Sept. 21 -->



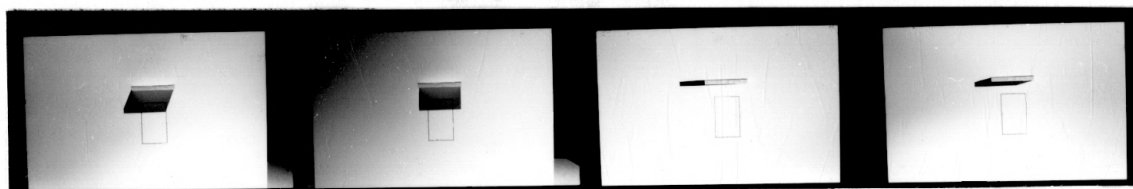
7 a.m.

8 a.m.

9 a.m.

10 a.m.

Dec. 21 -->

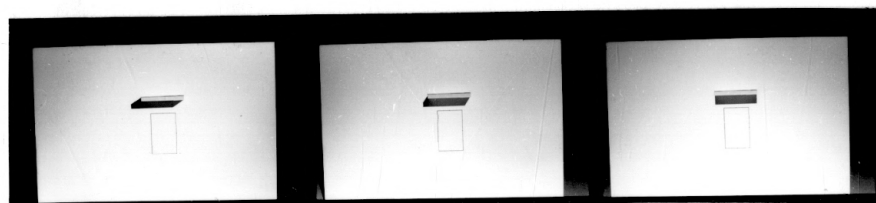


11 a.m.

12 p.m.

8 a.m.

9 a.m.



10 a.m.

11 a.m.

12 p.m.

## **B. Solar Position Charts**

For 0 to 64 degrees North latitudes at an interval of 8 degrees are included here listing the solar altitude and azimuth angles for 21st day of each month.

Reproduced from - "ASHRAE Fundamentals Handbook", 1981.

## CHAPTER 27

## 1981 Fundamentals Handbook

Table 2 Solar Position and Related Angles for 0 Deg North Latitude

DATE	Solar Time	Solar Position		Profile (Shadow Line) Angles										Angles of Incidence Vertical Surfaces										Solar Time						
	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM	
DEC	7	14	66			35	20	15	14	15	19	31	83					70	48	28	14	25	45	67	88			76	5	
	8	27	63			59	38	30	27	29	34	49	82					74	54	37	28	33	48	67	86			63	4	
	9	40	58			75	55	45	41	41	46	58	80					80	63	50	41	42	52	67	83			50	3	
	10	53	49			87	71	60	54	53	56	63	76					88	74	63	55	53	57	67	79			37	2	
	11	62	31			86	75	67	63	63	66	73	83	83				86	76	68	63	63	67	74	83	83			28	1
	12	67	0			90	81	73	68	67	68	73	81	73	81				90	81	74	68	67	68	74	81	23		12	
JAN	7	14	69		83	31	19	15	14	15	20	35					88	66	45	25	14	28	48	70				76	5	
	8	28	67			55	37	30	28	30	37	54	89					71	52	36	28	35	51	70	90			62	4	
NOV	9	42	63			71	54	45	42	43	49	63	85					77	61	48	42	45	55	70	86			48	3	
	10	54	54			84	70	60	55	55	59	67	80					85	72	62	56	55	60	70	82			36	2	
	11	65	35			84	75	69	65	66	69	76	86	86				85	76	69	66	66	70	77	86	86			25	1
	12	70	0			90	82	76	71	70	71	76	82	76	82				90	82	76	72	70	72	76	82	20		12	
FEB + OCT	7	15	79		53	25	18	15	15	18	25	54					79	57	36	18	19	37	58	79				75	5	
	8	29	78			73	46	35	30	30	34	45	69					81	62	44	32	31	43	60	79			61	4	
	9	44	75			82	63	51	45	44	48	58	75					85	69	55	46	44	51	64	79			46	3	
	10	58	69			89	76	66	60	58	61	67	78					89	78	68	61	58	61	69	79			32	2	
	11	72	54			87	80	75	72	72	74	79	85	85				87	81	75	72	72	74	79	86	86			18	1
12	79	0			90	86	82	82	80	79	80	82	82	86	82				90	86	82	80	79	82	86	86	11		12	
MAR + SEP	7	15	90	90	35	21	16	15	16	21	35	90				90	68	47	27	15	27	47	68	90				75	5	
	8	30	90	90	56	39	32	30	32	39	56	90				90	71	52	37	30	37	52	71	90				60	4	
	9	45	90	90	69	55	47	45	47	55	69	90				90	74	60	49	45	49	60	74	90				45	3	
	10	60	90	90	78	68	62	60	62	68	78	90				90	79	69	62	60	62	69	79	90				30	2	
	11	75	90	90	84	79	76	75	76	79	84	90				90	84	79	76	75	76	79	84	90				15	1	
	12	90	90	90	90	90	90	90	90	90	90	90				90	90	90	90	90	90	90	90	90				0	12	
APR + AUG	7	15	102	52	25	17	15	15	18	26	55					78	57	36	18	19	37	58	80					75	5	
	8	29	103	68	44	33	30	30	35	47	74					78	59	42	31	32	45	63	82					61	4	
	9	44	106	74	57	48	44	45	51	63	83					78	63	51	44	46	56	70	85					46	3	
	10	58	112	77	66	60	58	60	66	76	90					78	68	61	58	61	68	78	90					32	2	
	11	71	128	78	73	71	72	75	81	88						78	74	71	72	75	81	88						19	1	
	12	78	180	78	79	82	86	90								78	79	82	86	90									12	12
MAY + JUL	7	14	111	35	20	15	14	15	19	31	83					70	48	28	14	25	45	66	88					76	5	
	8	28	113	54	37	30	28	30	37	55						70	51	35	28	36	52	71						62	4	
	9	42	117	63	49	43	42	45	54	71						70	55	45	42	48	61	77						48	3	
	10	54	126	67	59	55	55	60	70	84						70	60	55	56	62	72	85						36	2	
	11	65	145	69	66	65	69	75	84							70	66	66	69	76	85							25	1	
	12	70	180	70	71	76	82	90								70	72	76	82	90								20	12	
JUN	7	14	114	31	19	15	14	15	20	35						67	45	25	14	28	48	70						76	5	
	8	27	117	49	34	29	27	30	38	59						67	48	33	28	37	54	74						63	4	
	9	40	122	58	46	41	41	45	55	75						67	52	42	41	50	63	80						50	3	
	10	53	131	63	56	53	54	60	71	87						67	57	53	55	63	74	88						37	2	
	11	62	149	66	63	63	67	75	86							67	63	63	68	76	86							28	1	
	12	67	180	67	68	73	81	90								67	68	74	81	90								23	12	
N NNW NW WNW W WSW SW SSW S SSE SE ESE N NNW NW WNW W WSW SW SSW S SSE SE ESE HOR PM																														

Dates vary year to year within plus or minus two days of the twenty-first day of the month.

Table 3 Solar Position and Related Angles for 8 Deg North Latitude

	Solar Time		Solar Position		Profile (Shadow Line) Angles										Angles of Incidence Vertical Surfaces										Solar Time					
Date	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM	
DEC	7	10	64			29	15	11	10	11	14	23	73						71	49	28	11	22	43	65	87		80	5	
	8	24	60			59	36	27	24	24	29	41	73						76	56	37	25	28	43	63	83		66	4	
	9	36	53			79	55	42	37	36	40	50	71						83	66	50	38	37	46	61	79		54	3	
	10	47	42				72	58	50	47	49	55	68	87					77	63	52	47	50	60	73	88		43	2	
	11	55	25				89	74	63	57	55	58	65	76					89	76	65	58	55	59	67	79		35	1	
	12	59	0				90	77	67	61	59	61	67	77					90	78	68	61	59	61	68	78		31	12	
JAN + NOV	7	11	68		89	27	16	12	11	12	16	27						90	68	46	25	11	25	46	68		79	5		
	8	25	64			55	35	27	25	26	31	46	82						73	53	36	25	31	47	66	86		65	4	
	9	38	57			75	54	43	38	38	43	55	77						81	63	48	39	39	49	64	82		52	3	
	10	49	46			89	71	58	51	49	52	59	73						89	75	62	53	49	53	63	76		41	2	
	11	58	28				87	74	65	60	58	61	68	80					87	76	66	60	58	62	70	81		32	1	
	12	62	0				90	78	69	64	62	64	69	78					90	80	71	64	62	64	71	80		28	12	
FEB + OCT	7	13	77		55	24	16	13	13	15	22	46						81	59	38	18	16	34	55	77		77	5		
	8	27	73		79	47	34	28	28	31	39	61						85	65	46	32	28	39	56	75		63	4		
	9	41	68		90	66	51	44	41	44	51	67						90	73	58	46	41	46	58	74		49	3		
	10	55	58			81	68	59	55	55	60	70	84						82	70	61	55	56	62	72	85		35	2	
	11	66	39				83	74	69	66	67	71	78	87					83	75	69	66	67	71	79	87		24	1	
	12	71	0				90	83	76	73	71	73	76	83					90	83	77	73	71	73	77	83		19	12	
MAR + SEP	7	15	88		37	21	16	15	16	20	32	82						70	49	29	15	25	45	66	88		75	5		
	8	30	85		62	41	33	30	31	37	51	82						75	56	39	30	34	49	67	86		60	4		
	9	44	82		76	58	49	45	45	51	63	82						80	65	52	45	46	55	69	84		46	3		
	10	59	76		85	73	64	60	59	63	71	82						85	74	65	60	59	64	72	83		31	2		
	11	73	63		85	79	75	73	74	77	82	88						85	79	75	73	74	77	82	89		17	1		
	12	82	0				90	87	84	83	82	83						90	87	84	83	82	83	84	87		8	12		
APR + AUG	6	2	101	8	3	2	2	2	2	3	8							79	56	34	11	12	34	57	79		88	6		
	7	16	100	60	29	20	17	16	19	27	53							81	59	38	20	19	36	56	78		74	5		
	8	31	99	76	49	37	32	31	35	45	68							82	64	46	34	32	43	60	78		59	4		
	9	46	98	82	63	52	46	46	50	60	77							84	69	56	47	46	53	65	80		44	3		
	10	60	99	85	73	65	61	61	64	72	83							85	75	66	61	61	65	73	84		30	2		
	11	75	105	86	81	77	75	75	78	82	88							86	81	77	75	75	78	82	88		15	1		
	12	86	180	86	87	87	89	90										86	87	87	89	90					4	12		
MAY + JUL	6	3	110	8	4	3	3	3	4	6	46							70	48	25	4	20	42	65	87		87	6		
	7	17	109	43	25	19	17	18	22	34	77							72	51	31	17	25	44	65	86		73	5		
	8	31	109	62	42	34	31	32	38	53	83							74	56	40	31	36	50	68	87		59	4		
	9	45	110	71	56	48	45	47	54	67	88							76	61	50	45	48	59	73	88		45	3		
	10	59	116	75	66	60	59	61	68	79								77	67	61	59	62	70	80		31	2			
	11	71	131	77	73	71	72	76	81	89								78	73	71	72	76	82	89		19	1			
	12	78	180	78	79	81		85	90									78	79	82	85	90					12	12		
JUN	6	3	113	8	4	3	3	3	5	9								67	44	22	3	23	46	68		87	6			
	7	17	112	39	23	18	17	18	23	38	89							69	48	28	17	28	47	68	90		73	5		
	8	31	113	57	40	33	31	33	40	57								71	52	37	31	37	53	71		59	4			
	9	44	115	66	53	46	44	47	55	71								72	58	48	44	50	61	76		46	3			
	10	57	122	71	63	58	58	61	69	82								74	64	58	58	63	72	83		33	2			
	11	69	139	74	70	69	71	76	83									74	70	69	71	76	83			21	1			
	12	75	180	75	76	79	84	90										75	76	79	90					15	12			
N NNW NW WSW SW SSW S SSE SE ESE N NNW NW WSW SW SSW S SSE SE ESE HOR PM																														

Dates vary year to year within plus or minus two days of the twenty-first day of the month.

# Fenestration

Table 4 Solar Position and Related Angles for 16 Deg North Latitude

	Solar Time		Solar Position		Profile (Shadow Line) Angle										Angles of Incidence Vertical Surfaces										Solar Time					
Date	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM	
DEC	7	7	63			21	10	8	7		9	15	58							72	50	28	8	19	41	63	86		83	5
	8	19	57			59	32	23	20	20	23	33	63						78	57	37	22	23	39	59	74		71	4	
	9	31	49			83	53	38	32	31	34	42	62						86	67	50	35	31	40	56	84		59	3	
	10	41	37				74	55	45	41	42	47	60	81						79	63	49	41	43	53	68	84		42	2
	11	48	21					72	58	51	48	50	57	70	88						76	63	52	48	51	61	74	89	49	1
	12	51	0					90	73	60	53	51	53	60	73						90	76	63	54	51	54	63	76	39	12
JAN - NOV	7	8	66			21	11	9	8	9	11	19	83						69	47	25	8	23	45	67	89		82	5	
	8	21	61			55	32	24	21	22	26	38	73						75	55	36	22	26	43	63	84		69	4	
	9	33	52			79	52	39	34	33	37	47	68						84	65	48	36	34	43	59	77		57	3	
	10	43	40				72	56	47	44	45	51	64	85						77	62	50	44	46	56	71	87	47	2	
	11	51	23				90	73	60	53	51	53	60	73						90	76	63	54	51	55	64	76	39	1	
	12	54	0					90	74	63	56	54	56	63	74						90	77	65	57	54	57	65	77	36	12
FEB - OCT	7	11	75		56	21	14	11	11	13	18	38							82	60	39	18	14	32	54	76		79	5	
	8	25	70		85	48	32	26	25	27	34	53							88	68	48	32	25	34	52	72		65	4	
	9	38	62			70	51	42	38	39	45	59	83						77	60	46	38	41	52	68	86		52	3	
	10	50	50			86	69	57	51	50	53	62	76						87	73	61	52	50	55	66	79		40	2	
	11	59	30				86	74	65	60	60	63	70	81						86	75	66	61	60	64	72	82	31	1	
	12	63	0				90	79	70	65	63	65	70	79						90	80	71	65	63	65	71	80	27	12	
MAR - SEP	7	14	86		39	21	16	14	15	19	30	74							72	51	30	15	23	43	64	86		76	5	
	8	29	81		67	43	33	29	29	34	46	74							78	59	42	30	31	45	63	82		61	4	
	9	43	75		82	62	50	44	43	47	56	74							85	69	55	45	43	50	63	79		47	3	
	10	56	64			77	66	59	56	58	64	74	88						79	68	60	56	59	66	76	88		34	2	
	11	68	44				82	74	70	68	70	74	81	90						82	75	70	68	70	75	82	90	22	1	
	12	74	0				90	84	79	75	74	75	79	84						90	84	79	75	74	75	79	84	16	12	
APR - AUG	6	3	101	16	6	4	3	3	4	6	16								79	56	34	12	12	34	56	79		87	6	
	7	17	97	68	32	22	18	18	20	27	50								83	62	41	23	19	34	54	76		73	5	
	8	32	94	84	54	39	33	32	35	43	63								87	68	50	36	32	40	56	74		58	4	
	9	46	90	90	70	56	48	46	48	56	70								90	74	61	50	46	50	61	75		44	3	
	10	61	85		80	70	63	61	62	67	76	87								81	71	64	61	62	68	77	88		29	2
	11	75	75		88	82	78	75	75	77	81	86							88	82	78	75	75	77	81	86		15	1	
	12	86	0				90	88	87	86	86	86	86	87	88					90	88	87	86	86	86	87	88	4	12	
MAY - JUL	6	5	109	16	8	6	5	6	7	12	59								71	48	26	6	20	42	64	87		85	6	
	7	19	106	51	29	22	19	20	24	36	72								75	54	34	20	25	42	63	84		71	5	
	8	33	104	70	48	37	33	34	39	51	77								79	60	44	34	36	47	64	83		57	4	
	9	47	102	79	62	52	48	48	53	63	81								82	67	55	48	48	56	68	83		43	3	
	10	61	103	83	73	65	62	62	66	74	85								84	74	66	62	62	67	75	85		29	2	
	11	75	108	85	80	77	75	76	79	83	89								85	80	77	75	76	79	83	89		15	1	
	12	86	180	86	86	87	88	90											86	86	87	88	90					4	12	
JUN	6	6	113	16	9	7	6	7	9	16																		84	6	
	7	20	110	47	28	22	20	21	26	40	82																	70	5	
	8	33	108	65	46	37	33	35	41	55	83								75	57	42	34	37	51	68	86		57	4	
	9	47	107	74	59	51	47	49	55	67	85								78	64	53	47	50	59	72	87		43	3	
	10	61	110	79	69	63	61	62	68	77	88								81	71	64	61	63	69	78	89		29	2	
	11	74	120	82	77	75	74	76	80	86									82	77	75	74	76	80	86			7	12	
	12	83	180	83	83	85	87	90											83	83	85	87	90							
				N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSZ	SW	SSW	S	SSE	SE	ESE	HOR	PM	

Dates vary year to year within plus or minus two days of the twenty-first day of the month.

Table 5 Solar Position and Related Angles for 24 Deg North Latitude

DATE	Solar Time		Solar Position		Profile (Shadow Line) Angles													Angles of Incidence Vertical Surfaces													Solar Time	
	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM			
DEC	7	3	63			10	5	4	3	3	4	7	33					72	50	28	6	18	40	63	85				87	5		
	8	15	55			56	26	18	15	15	18	25	52					80	58	37	19	18	36	57	78				75	4		
	9	26	46			88	50	34	52									89	69	50	33	26	34	51	71				64	3		
		34	34				74	51	39	35	35	39	51	74					81	63	47	36	36	47	63	81			56	2		
	11	40	18				70	53	44	40	42	48	62	85					76	60	47	41	44	55	70	87	50		50	1		
JAN + NOV	12	43	0				90	67	52	45	43	45	52	67					90	74	59	47	43	47	59	74	47		47	12		
	7	5	66			13	7	5	5	5	7	11	69					69	47	25	5	21	43	66	88				85	5		
	8	17	58			53	27	20	17	17	20	30	62					77	56	36	19	21	39	60	81				73	4		
	9	28	49			83	50	35	29	28	31	39	59					87	67	48	33	28	38	54	73				62	3		
	10	37	36			73	52	42	38	38	43	56	79					79	62	47	38	39	50	66	83				53	2		
FEB + OCT	11	44	20				71	55	47	44	45	52	66	87					76	61	49	44	47	58	72	88			46	1		
	12	46	0				90	70	56	48	46	48	56	70					90	75	61	50	46	50	61	75	44		44	12		
	7	9	74	55		18	11	9	9	10	14	30						84	62	40	18	11	30	52	74				81	5		
	8	22	66			48	30	24	22	23	29	45	87					70	50	32	22	30	48	68	89			68	4			
	9	34	57			73	50	39	34	35	39	51	75					80	62	46	35	36	47	63	81			56	3			
MAR + SEP	10	45	44				70	55	47	45	46	54	68	88					75	61	49	45	48	59	73		89		45	2		
	11	52	25			88	72	60	54	52	55	62	75					89	75	63	55	52	56	65	78			38	1			
	12	55	0				90	75	64	57	55	57	64	75					90	77	66	58	55	58	66	77	35		35	12		
	7	14	84	41	21	16	14	14	17	27	66							74	53	32	15	21	41	62	84			76	5			
	8	27	77	73	44	32	28	27	31	41	66							82	62	44	30	29	41	59	78			63	4			
APR + AUG	9	40	68		90	65	50	42	40	43	50	66						90	73	57	45	40	45	58	73			50	3			
	10	52	55			82	68	58	53	53	57	66	80					84	71	60	53	53	59	69	82			38	2			
	11	62	33			84	74	66	62	62	66	73	84					85	75	67	63	62	67	75	85			28	1			
	12	66	0				90	80	73	68	66	68	73	80					90	81	73	68	66	68	73	81	24		24	12		
	6	5	101	24	9	6	5	5	6	8	22							79	57	35	13	12	33	56	78			85	6			
MAY + JUL	7	18	95	76	36	23	19	18	20	27	47							85	64	43	25	19	33	52	73			72	5			
	8	32	89		60	42	34	32	34	41	57	88							72	54	39	32	38	52	70	89			58	4		
	9	46	82		76	60	50	46	47	52	64	82						80	65	53	46	47	56	69	84			44	3			
	10	59	72		87	75	65	60	59	62	69	79						88	77	67	61	59	63	70	81			31	2			
	11	71	52			88	81	75	72	71	73	78	85					88	81	75	72	71	74	78	85			19	1			
JUN	12	78	0				90	85	81	79	78	79	81	85					90	85	81	79	78	79	81	85	12		12			
	6	8	108	24	12	9	8	8	11	17	63							72	50	28	9	20	42	64	86			82	6			
	7	21	103	59	34	24	21	22	26	36	67							78	57	38	23	25	41	61	81			69	5			
	8	35	98	78	53	41	35	35	39	49	71							83	65	49	37	36	45	61	79			55	4			
	9	48	94	87	69	56	50	48	51	59	74							88	73	60	51	48	53	64	78			42	3			
JUN	10	62	88		80	70	64	62	63	69	77	89							81	71	65	62	64	70	79	89			28	2		
	11	76	77		88	82	78	76	76	78	81	87							88	82	78	76	76	78	82	87			14	1		
	12	86	0				90	88	87	86	86	86	87	88					90	88	87	86	86	86	87	88	4		4	12		
	6	9	112	24	13	10	9	10	13	22	85							69	47	25	9	23	45	67	89			81	6			
	7	22	107	55	33	25	22	23	28	41	76							75	54	35	23	28	44	64	85			68	5			
JUN	8	36	103	73	51	40	36	36	41	53	76							80	62	47	37	37	48	64	82			54	4			
	9	49	99	82	66	55	50	49	53	63	78							84	70	58	50	50	56	67	81			41	3			
	10	63	95	87	77	68	64	63	65	72	81							88	78	69	64	63	66	73	82			27	2			
	11	76	91	90	84	80	77	76	77	80	85							90	85	80	77	76	77	80	85			14	1			
	12	89	0				90	90	90	89	89	89	90	90					90	90	89	89	89	89	89	90	90	1	1	12		
N NNW NW WNW W WSW SW SSW S SSE SE ESE N NNW NW WNW W WSW SW SSW S SSE SE ESE HOR PM																																

es vary year to year within plus or minus two days of the twenty-first day of the month.

# CHAPTER 27

# 1981 Fundamentals Handbook

Table 6 Solar Position and Related Angles for 32 Deg North Latitude

DATE	Solar Time		Solar Position		Profile (Shadow Line) Angles										Angles of Incidence Vertical Surfaces										Solar Time					
	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM	
DEC	8	10	54			50	19	13	11	10	12	17	37						81	59	37	17	14	33	55	77		80	4	
	9	20	44				45	28	22	20	21	26	42	86					70	50	31	20	29	47	68	89		70	3	
	10	28	31				74	45	33	28	28	31	41	65					82	63	44	31	29	41	58	78		62	2	
	11	33	16				66	46	36	33	34	40	53	81					76	58	42	33	36	49	66	85	57	1		
	12	35	0				90	61	44	37	35	37	44	61					90	72	54	40	35	40	54	72	55	12		
JAN + NOV	7	-1	65			4	2	2	1	2	2	3	32						70	47	25	3	20	43	65	88		89	5	
	8	13	56			48	22	15	13	13	15	22	49						79	57	36	17	17	36	57	79		77	4	
	9	22	46			88	46	30	24	22	24	31	48						89	68	48	31	22	32	50	70		68	3	
	10	31	33				73	47	36	31	31	35	46	71					81	62	45	33	32	44	61	80		59	2	
	11	36	18				68	49	39	36	37	44	58	83					76	59	44	36	40	52	68	86	54	1		
FEB + OCT	12	38	0				90	64	48	40	38	40	48	64					90	72	56	43	38	43	56	72	52	12		
	7	7	73		52	14	9	7	7	8	10	22							85	62	40	18	9	29	51	73		83	5	
	8	18	64			46	27	20	19	19	24	37	79						72	51	32	19	26	45	65	86		72	4	
	9	29	53			76	48	35	30	30	33	43	66						83	64	46	33	30	41	58	77		61	3	
	10	38	39				70	52	42	39	40	46	59	82					77	61	47	39	41	52	68	85		52	2	
MAR + SEP	11	45	21				70	55	47	45	47	54	68	89					75	61	50	45	49	59	73	89	45	1		
	12	47	0				90	70	57	49	47	49	57	70					90	75	61	51	47	61	61	75	43	12		
	7	13	82		42	21	15	13	13	16	24	58							76	54	33	15	19	39	60	82		77	5	
	8	25	73		78	45	31	26	25	28	36	58							85	65	46	30	26	37	55	75		65	4	
	9	37	62			69	50	40	37	38	44	58	83						76	59	45	37	40	52	68	86		53	3	
APR + AUG	10	47	47			88	69	56	49	47	50	58	72						88	73	60	50	47	52	63	77		43	2	
	11	55	27				87	72	62	56	55	58	65	78					88	75	64	57	55	59	68	80		35	1	
	12	58	0				90	77	66	60	58	60	66	77					90	78	68	61	58	61	68	78	32	12		
	6	6	100	32	11	7	6	6	7	11	26								80	58	36	14	12	33	55	77		84	6	
	7	19	92	84	39	25	20	19	20	27	44								88	67	46	27	19	31	50	71		71	5	
MAY + JUL	8	31	84		65	44	35	32	33	38	52	80							76	58	41	32	35	48	66	85		59	4	
	9	44	74		83	63	51	45	44	48	57	74							85	69	56	46	44	51	63	79		46	3	
	10	56	60			80	67	59	56	57	62	71	85						81	70	61	56	57	64	74	86		34	2	
	11	65	37				83	74	68	66	70	77	87							84	75	69	66	66	71	78	87		25	1
	12	70	0				90	82	75	71	70	71	75	82					90	82	76	71	70	71	76	82	20	12		
JUN	6	10	107	32	16	12	10	11	13	22	63								73	51	30	12	20	41	63	85		80	6	
	7	23	100	67	38	27	23	23	27	36	63								81	60	41	26	25	39	58	79		67	5	
	8	35	93	86	59	44	37	35	38	47	65								88	70	53	40	36	43	57	74		55	4	
	9	48	85		75	60	52	48	49	55	67	85							79	65	54	48	50	59	72	86		42	3	
	10	61	73		87	75	66	62	61	64	70	81							87	77	68	62	61	64	72	82		29	2	
	11	72	52				88	81	76	73	72	74	79	85					88	81	76	73	72	74	79	85		18	1	
	12	78	0				90	85	81	79	78	79	81	85					90	85	82	79	78	79	82	85	12	12		
	5	1	118	1	1	1	1	1	1	2									62	40	17	5	28	50	73			89	7	
	6	12	110	32	18	13	12	13	16	27	79								70	48	27	12	23	44	66	88		78	6	
	7	24	103	63	38	28	25	25	29	41	71								78	58	39	26	28	42	62	82		66	5	
	8	37	97	81	57	44	38	37	41	50	70								85	67	51	40	37	46	60	77		53	4	
	9	50	89		72	59	52	50	52	59	72	90							76	63	53	50	53	62	75	90		40	3	
	10	62	80		84	73	66	63	63	67	74	85							84	75	67	63	63	67	75	85		28	2	
	11	74	61			86	80	76	74	75	78	82	88							86	80	76	74	75	78	82	88		16	1
	12	81	0				90	87	84	82	81	82	84	87					90	87	84	82	81	82	84	87	9	12		
N NNW NW WNW W WSW SW SSW S SSE SE ESE N NNW NW WNW W WSW SW SSW S SSE SE ESE HOR PM																														

Dates vary year to year within plus or minus two days of the twenty-first day of the month.



**Table 7 Solar Position and Related Angles for 40 Deg North Latitude**

Dates vary year to year within plus or minus two days of the twenty-first day of the month.

1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 26

# Fenestration

Table 8 Solar Position and Related Angles for 48 Deg North Latitude

	Solar Time		Solar Position		Profile (Shadow Line) Angles												Angles of Incidence Vertical Surfaces												Solar Time						
Date	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM						
DEC	8	1	53			5		1	1	1	1	1	2						82	60	37	15	8	30	53	75		89	4						
	9	8	41				24	12	9	8	8	10	17	63						72	50	28	9	20	42	64	86		82	3					
	10	14	28				68	27	17	14	14	15	21	40					84	63	41	22	15	31	52	74		76	2						
	11	17	14					51	27	20	17	18	21	31	66					76	55	35	19	22	40	61	82	73	1						
	12	19	20					90	41	25	20	19	20	25	41					90	69	48	29	19	29	48	69	71	12						
JAN + NOV	8	3	55			20	6	4	4	4	4	6	15						80	58	36	13	10	32	55	77		87	4						
	9	11	43				29	16	12	11	12	15	25	78					70	48	27	11	23	44	66	88		79	3						
	10	17	29				68	32	21	17	17	19	26	48					83	62	41	23	18	34	54	75	73	2							
	11	21	15					55	32	24	21	21	25	37	71					76	55	36	22	25	42	62	83	69	1						
	12	22	0					90	47	30	24	22	24	30	47					90	69	49	31	22	31	49	69	68	12						
FEB + OCT	7	2	72		23	4	2	2	2	2	3	6							86	63	41	18	5	27	49	72		88	5						
	8	11	60			37	18	13	11	11	14	21	56						75	53	32	13	19	39	61	83		79	4						
	9	19	47			83	39	25	20	19	21	27	45						88	67	46	27	19	31	50	71		71	3						
	10	25	33				69	41	30	26	26	30	40	66					81	61	42	28	27	41	59	79		65	2						
	11	30	17					63	42	33	30	31	36	51	81					75	56	40	30	34	48	66	85	60	1						
MAR + SEP	12	31	0					90	58	41	33	31	33	41	58					90	71	53	38	31	38	53	71	59	12						
	7	10	79		42	18	12	10	10	12	18	42							79	57	35	15	15	35	57	79		80	5						
	8	20	67			44	27	21	20	21	26	42	88						70	49	30	20	29	48	68	89		70	4						
	9	28	53			75	46	34	29	28	32	42	66						83	63	45	31	29	41	58	78		62	3						
	10	35	38				70	49	39	36	36	42	55	80						78	60	45	36	38	50	66	84		55	2					
APR + AUG	11	40	20					68	52	43	40	42	49	63	87					75	59	46	40	44	56	71	88		50	1					
	12	42	0					90	67	52	44	42	44	52	67					90	73	58	47	42	47	58	73	48	12						
	6	9	98	48	17	11	9	9	10	14	31								82	60	38	17	12	31	53	75		81	6						
	7	19	87		46	27	20	19	20	24	38	80							72	51	31	19	27	45	66	87		71	5						
	8	29	75		77	47	34	29	29	32	42	64							84	64	46	32	29	40	58	77		61	4						
MAY + JUL	9	38	61			70	51	42	38	39	45	58	82						77	60	46	38	41	52	68	85		52	3						
	10	46	45				70	56	48	46	48	55	69	90					75	61	50	46	50	60	74	90		44	2						
	11	51	24				89	72	60	53	52	54	61	74					89	75	63	54	52	55	65	77		39	1						
	12	54	0					90	74	62	56	54	56	62	74					90	77	65	57	54	57	65	77	36	12						
	5	5	114	13	7	6	5	6	8	15									66	43	21	6	25	47	69			85	7						
JUN	6	15	104	48	24	17	15	15	18	27	60								77	55	34	17	20	39	60	81		75	6						
	7	25	93	83	47	32	26	25	27	34	54								87	67	47	31	25	35	53	72		65	5						
	8	35	82		71	49	39	35	35	41	53	78							78	61	45	36	37	49	65	83		55	4						
	9	44	68		89	68	54	46	44	47	54	69							89	74	59	48	44	49	60	75		46	3						
	10	53	51			85	70	60	54	53	57	65	78						86	73	62	55	53	58	68	80		37	2						
JUN	11	59	29				86	74	65	61	60	63	70	81					87	76	67	61	60	64	71	82		31	1						
	12	62	0					90	78	69	64	62	64	69	78					90	80	71	64	62	64	71	80	28	12						
	5	8	117	17	10	8	8	9	12	24									64	42	20	9	28	50	72			82	7						
	6	17	106	48	26	19	17	18	22	33	70								75	53	33	18	23	42	63	84		73	6						
	7	27	96	79	47	33	28	27	30	39	61								85	65	46	31	28	38	56	75		63	5						
	8	37	85		69	50	41	37	38	44	58	83							76	59	45	37	40	52	68	86		53	4						
	9	47	72		86	67	55	48	47	50	58	74							87	72	59	50	47	52	63	78		43	3						
10	56	55			83	70	61	56	56	60	69	81						85	73	63	57	56	62	71	83		34	2							
JUN	11	63	31				86	75	67	63	63	66	73	83					86	76	68	64	63	67	74	84		27	1						
	12	65	0					90	80	72	67	65	67	72	80					90	81	73	67	65	67	73	81	25	12						
N NNW NW WNW W WSW SW SSW S SSE SE ESE N NNW NNW NNW W WSW SW SSW S SSE SE ESE HOR PM																																			

Dates vary year to year within plus or minus two days of the twenty-first day of the month.

Table 9 Solar Position and Related Angles for 56 Deg North Latitude

	Solar Time		Solar Position		Profile (Shadow Line) Angles												Angles of Incidence Vertical Surfaces												Solar Time	
Date	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM	
DEC	9	2	40				6	3	2	2	2	2	4	23						72	50	27	5	18	41	63	85	88	3	
	10	7	27				53	14	9	7	7	7	10	21						85	63	40	19	8	28	50	73	88	2	
	11	10	14					35	16	11	10	10	12	18	48						76	54	32	13	17	37	59	82	80	1
	12	11	0					90	26	15	11	11	11	15	26						90	68	46	25	11	25	46	68	79	12
JAN + NOV	9	5	42				15	8	6	5	5	7	12	58						71	48	26	6	20	42	64	87	85	3	
	10	10	28				59	20	13	10	10	11	15	31						84	62	40	19	12	30	52	74	80	2	
	11	13	14					43	21	15	13	13	16	24	59						76	54	33	15	19	39	60	82	77	1
	12	14	0					90	33	19	15	14	15	19	33						90	68	47	26	14	26	47	68	76	12
FEB + OCT	8	7	59			26	11	8	7	7	8	13	39						76	54	32	11	16	37	59	82	83	4		
	9	13	46			88	31	19	14	13	15	19	33						89	68	46	26	13	27	47	69	77	3		
	10	19	31				66	33	23	19	19	22	30	55						82	61	40	23	21	36	56	77	71	2	
	11	22	16					56	33	25	22	23	27	40	74						75	55	36	23	27	43	63	84	68	1
MAR + SEP	12	23	0					90	48	31	25	23	25	31	48						90	69	49	32	23	32	49	69	67	12
	7	8	77		40	15	10	9	8	10	14	34						80	58	36	15	13	33	55	78			82	5	
	8	16	64			41	24	18	16	17	21	34	80						71	50	30	17	25	44	66	87		74	4	
	9	23	50			78	43	29	24	23	26	34	56						85	65	45	29	24	36	54	74		67	3	
APR + AUG	10	29	35			69	44	33	29	30	34	46	72						79	60	43	31	31	44	62	81		61	2	
	11	33	18				64	45	36	33	34	40	55	83						75	57	41	33	37	50	67	86	57	1	
	12	34	0				90	60	44	36	34	36	44	60						90	72	54	40	34	40	54	72	56	12	
	5	1	109	4	2	2	1	2	2	3	21					71	49	26	4	19	41	64	86					89	7	
MAY + JUL	6	10	97	56	19	12	10	10	11	15	32					84	61	39	19	12	30	52	74					80	6	
	7	18	84		49	27	20	18	19	23	34	72					74	53	33	19	24	42	63	84				72	5	
	8	26	71		83	48	33	27	26	29	36	56					87	67	48	32	26	36	53	73				64	4	
	9	34	56			74	50	39	34	34	39	50	74				81	62	46	35	35	46	62	81				56	3	
JUN	10	40	40				71	53	43	40	41	47	61	84						77	61	47	40	43	54	69	86		50	2
	11	44	21				70	55	47	44	46	53	67	88						75	61	49	44	48	58	73	89	46	1	
	12	46	0				90	69	55	48	46	48	55	69						90	74	60	50	46	50	60	74	44	12	
	4	1	126	2	1	1	1	1	2	7						54	32	10	13	36	58	81						89	8	
JUL	5	8	113	21	12	9	8	9	12	22						67	45	23	9	25	47	69						82	7	
	6	16	102	56	28	20	17	17	20	28	57					79	58	37	20	20	37	58	79					74	6	
	7	25	89		51	33	27	25	26	33	50	89					70	51	33	25	33	50	69	89				65	5	
	8	33	76		77	51	39	34	33	37	48	70					83	64	47	36	34	44	60	79				57	4	
AUG	9	41	62			72	54	45	41	42	48	61	83							78	62	48	41	44	54	69	86		49	3
	10	48	44				71	58	50	48	50	57	70	89							76	62	52	48	51	61	75	89	42	2
	11	52	23				89	73	61	54	52	55	62	74						89	76	64	55	52	56	65	77		38	1
	12	54	0				90	74	63	56	54	56	63	74							90	77	65	57	54	57	65	77	36	12
SEP	4	4	127	7	5	4	4	5	8	28						53	31	9	15	37	60	82						86	8	
	5	11	115	25	15	12	11	13	17	31						65	43	23	12	28	49	71						79	7	
	6	28	92	87	52	36	29	28	30	37	56					89	69	50	34	28	36	53	72					62	5	
	7	28	92	87	52	36	29	28	30	37	56					89	69	50	34	28	36	53	72					62	5	
OCT	8	36	79		75	52	41	36	36	41	53	75					81	63	48	37	37	48	63	81				54	4	
	9	44	64			71	55	47	44	45	52	66	86							76	61	50	44	47	57	72	88		46	3
	10	51	46			89	72	59	53	51	53	61	74							89	75	63	54	51	55	64	77		39	2
	11	56	25				88	74	63	57	56	58	65	77						89	76	65	58	56	59	68	79		34	1
NOV	12	57	0				90	76	66	59	57	59	66	76							90	78	68	60	57	60	68	78	33	12
				N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	N	NNW	NW	WNW	W	WSW	SW	SSW	S	SSE	SE	ESE	HOR	PM	

Dates vary year to year within plus or minus two days of the twenty-first day of the month.

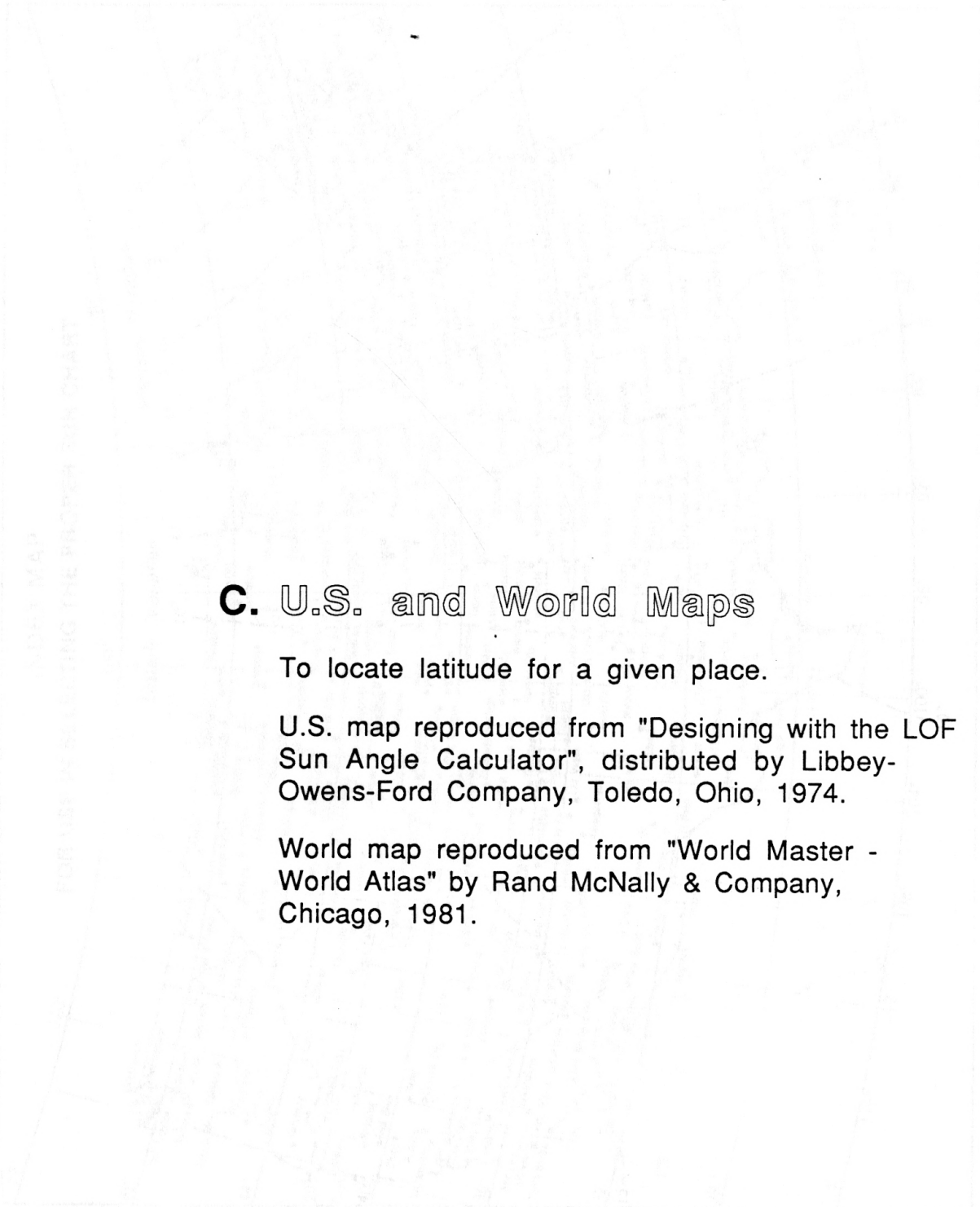
# CHAPTER 27

# 1981 Fundamentals Handbook

Table 10 Solar Position and Related Angles for 64 Deg North Latitude

	Solar Time	Solar Position		Profile (Shadow Line) Angles												Angles of Incidence Vertical Surface												Solar Time			
Date	AM	ALT	AZ	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	HOR	PM		
DEC	11	2	14					7	3	2	2	2	2	3	11					76	54	31	9	14	36	59	81	88			
	17	3	0					90	7	4	3	3	3	4	7					90	68	45	23	3	23	45	68	87		12	
JAN	10	3	28				27	6	4	3	3	3	4	10					84	62	40	17	6	28	51	73	87		2		
+ NOV	11	5	14					20	9	6	5	5	6	10	32					76	54	31	10	15	37	59	82	85		1	
	12	6	0					90	15	8	6	6	6	8	15					90	68	45	23	6	23	45	68	84		12	
FEB	8	3	58					5	3	3	3	3	5	17					77	54	32	9	14	36	58	81		87	4		
+ OCT	9	8	45			11		20	11	8	8	8	11	19	86					68	46	24	8	23	45	67	90		82	3	
	10	12	30					58	23	15	12	12	14	19	39					83	61	39	19	14	32	54	75		78	2	
	11	14	15					44	23	16	14	15	18	27	64					75	54	33	16	21	40	61	83	76		1	
	12	15	0					90	35	21	16	15	16	21	35					90	68	47	27	15	27	47	68	75		12	
MAR	7	7	76			36		12	8	7	7	8	11	26					81	59	37	15	11	32	54	77		83	5		
+ SEP	8	13	63					37	19	14	13	13	16	26	69					73	51	30	14	22	42	63	85		77	4	
	9	18	48					81	37	24	19	18	20	26	44					87	66	45	26	18	31	51	72		72	3	
	10	22	33					67	37	27	23	23	26	36	63					81	60	41	25	24	39	58	79		68	2	
	11	25	17						59	37	28	25	26	31	45	78				75	55	37	26	30	45	64	85		65	1	
	12	26	0					90	52	35	28	26	28	35	52					90	70	51	34	26	34	51	70		64	12	
APR	5	4	108	12	6	4	4	4	5	9	45					72	49	27	6	19	41	64	86				86	7			
+ AUG	6	10	95	64	22	13	11	10	12	16	32					85	63	41	20	12	29	51	73				80	6			
	7	17	82		51	27	20	17	17	21	31	64					77	55	35	19	22	40	61	82				73	5		
	8	23	67			48	31	25	23	25	31	48	90					69	50	32	23	32	49	69	90			67	4		
	9	29	52			77	48	35	30	29	33	42	65					84	64	46	32	30	41	58	77			61	3		
	10	34	36				71	48	38	34	34	39	52	77					79	61	45	35	36	48	64	83		56	2		
	11	37	18					67	49	40	37	38	44	59	84					75	58	44	37	40	53	69	67		53	1	
	12	38	0					90	64	47	40	38	40	47	64					90	72	56	43	38	43	56	72		52	12	
MAY	4	6	125	10	7	6	6	7	11	31						55	33	11	14	36	58	80					84	8			
+ JUL	5	12	112	29	16	13	12	12	16	28	88					68	47	26	12	25	46	68	90				78	7			
	6	18	99	64	32	22	18	18	21	29	54					81	60	40	22	20	36	76	77				72	6			
	7	24	86			56	35	27	25	26	31	45	81				74	54	36	25	30	46	66	86				66	5		
	8	31	71		83	53	38	32	31	34	42	62					87	67	50	36	31	40	56	74				59	4		
	9	37	56			76	54	42	37	37	42	53	75					81	64	48	38	38	48	63	81			53	3		
	10	42	39				72	55	45	42	43	49	62	83					78	62	49	42	44	54	69	85		48	2		
	11	45	70					71	56	48	45	47	53	67	88					76	61	50	45	48	59	73	88		45	1	
	12	46	0					90	70	56	48	46	48	56	70					90	75	61	50	46	50	61	75		44	12	
JUN	4	9	126	15	10	9	9	11	17	47						54	32	12	17	37	59	82					81	8			
	5	15	114	33	20	16	15	16	21	36						67	46	26	15	28	48	69					75	7			
	6	21	101	64	35	25	21	21	25	34	62					80	59	39	24	23	39	58	79				69	6			
	7	28	87			57	38	30	28	29	35	51	85				72	53	37	28	34	49	68	88				62	5		
	8	34	73		81	55	41	35	34	37	47	67					85	67	50	37	34	43	58	76				56	4		
	9	40	58			75	55	45	40	41	46	58	79						80	64	50	41	42	51	66	83		50	3		
	10	45	40				73	57	48	45	46	53	65	85						77	63	51	45	48	57	71	87		45	2	
	11	48	21					72	58	51	48	50	57	70	89						76	63	53	48	52	61	74	89		42	1
	12	49	0					90	72	59	52	49	52	59	72						90	76	63	53	49	53	63	76		41	12
N NNW NW WNW W WSW SW SSW S SSE SE ESE N NNW NW WNW W WSW SW SSW S SSE SE ESE HOR PM																															

Dates vary year to year within plus or minus two days of the twenty-first day of the month.



ADDITIONAL MAP  
FOR USE IN SELECTING THE PROPER SUN CHART

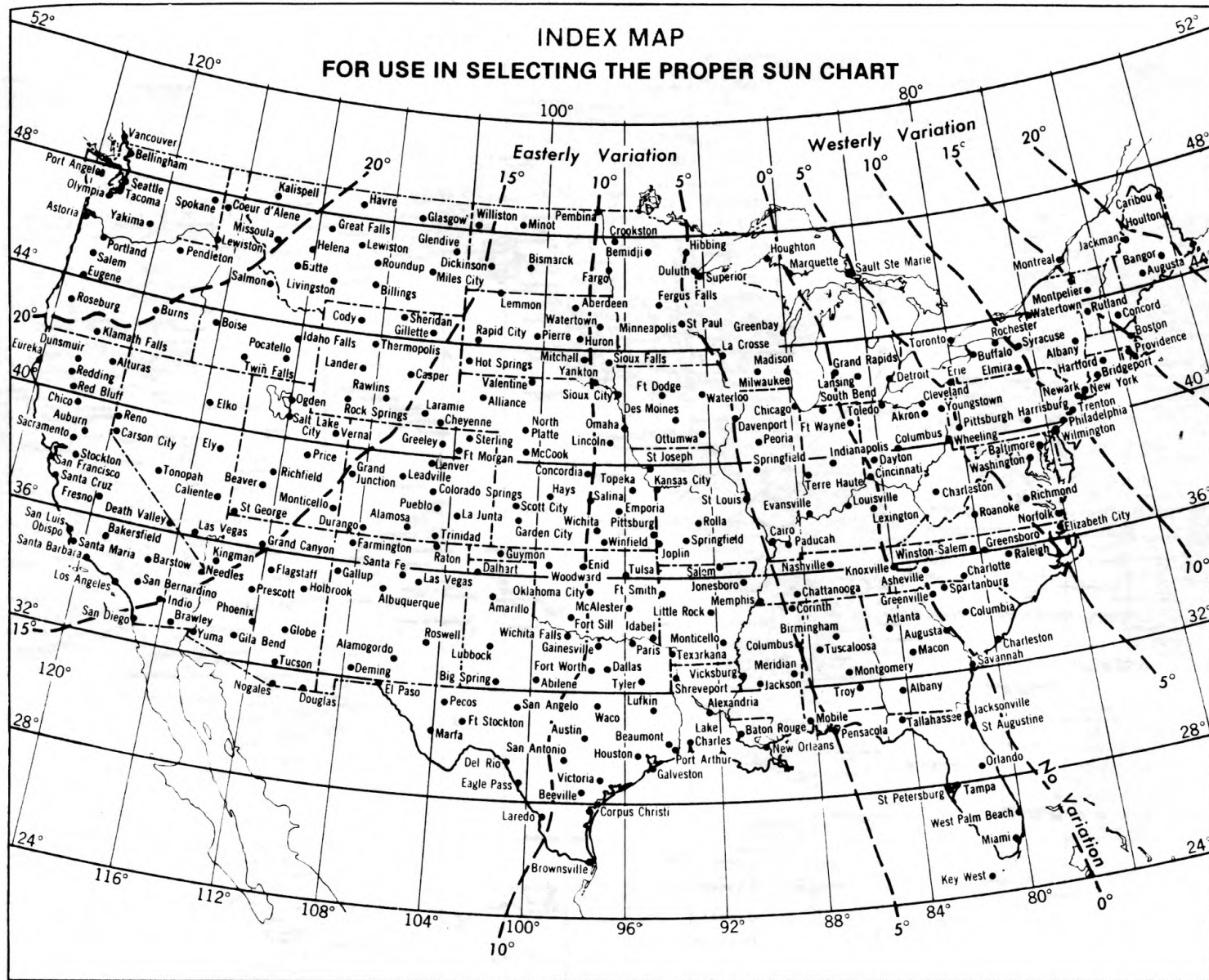
## C. U.S. and World Maps

To locate latitude for a given place.

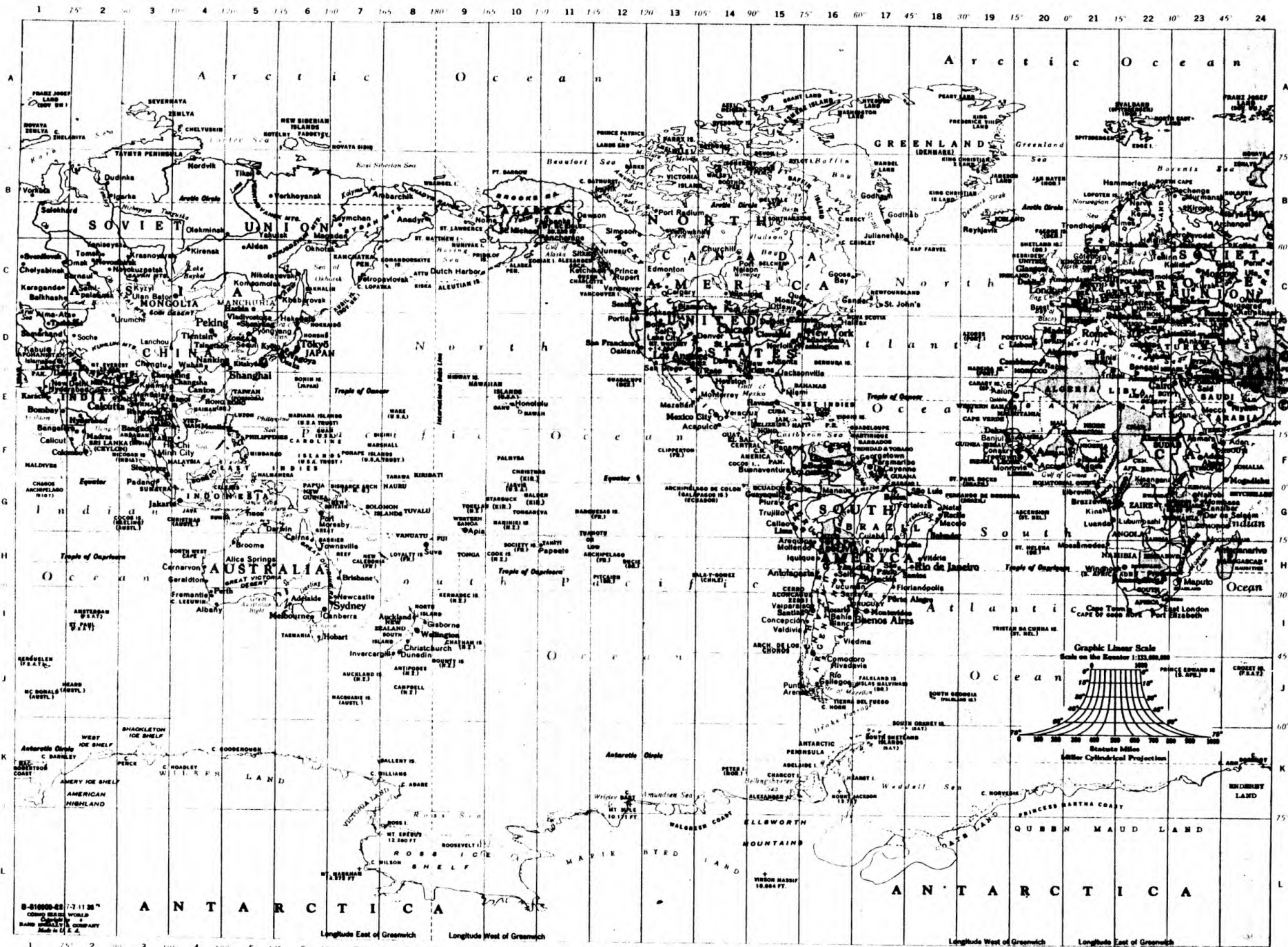
U.S. map reproduced from "Designing with the LOF Sun Angle Calculator", distributed by Libbey-Owens-Ford Company, Toledo, Ohio, 1974.

World map reproduced from "World Master - World Atlas" by Rand McNally & Company, Chicago, 1981.

INDEX MAP  
FOR USE IN SELECTING THE PROPER SUN CHART









## D. Sizing Overhang

For a south facing 3'x5' window at 40 degrees north latitude using Graph developed by - Dave Boyd of Engineering Extension Programs. Distributed by the Technical Energy Information Services of the KSU Cooperative Extension Services, 1983.

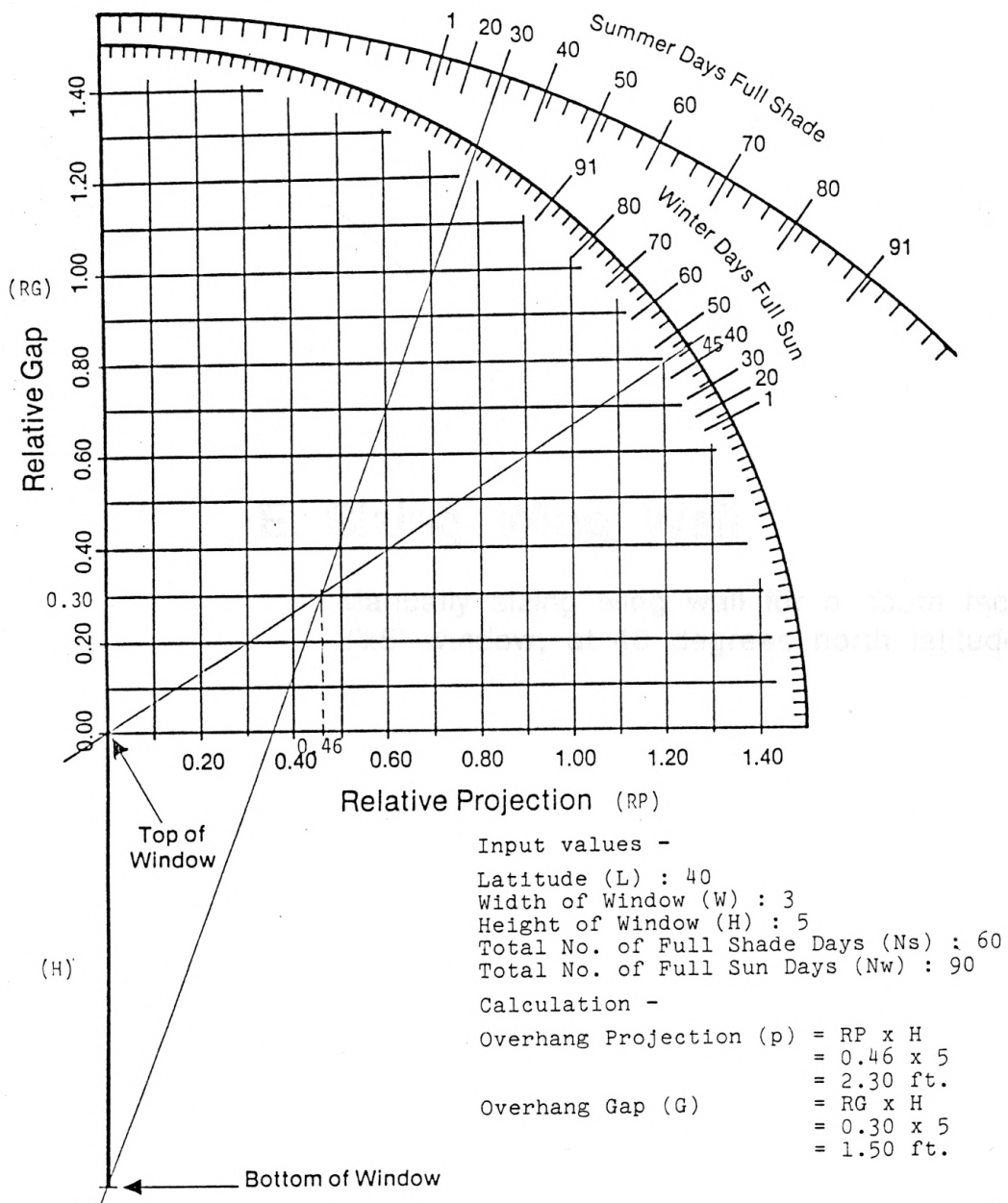


Fig. 6

Part 1: Sizing Wing Wall

1.00 ft. x 1.00 ft.

Wing Wall Dimensions:

Top: 1.00 ft. x 1.00 ft. x 1.00 ft.

Bottom: 1.00 ft. x 1.00 ft. x 1.00 ft.

Left Side: 1.00 ft. x 1.00 ft. x 1.00 ft.

Right Side: 1.00 ft. x 1.00 ft. x 1.00 ft.

Front: 1.00 ft. x 1.00 ft. x 1.00 ft.

Back: 1.00 ft. x 1.00 ft. x 1.00 ft.

Left Side: 1.00 ft. x 1.00 ft. x 1.00 ft.

Right Side: 1.00 ft. x 1.00 ft. x 1.00 ft.

1.00 ft.

1.00 ft. x 1.00 ft. x 1.00 ft.

1.00 ft. x 1.00 ft. x 1.00 ft.

1.00 ft. x 1.00 ft. x 1.00 ft.

1.00 ft. x 1.00 ft. x 1.00 ft.

## E. Sizing Wing Wall

Manually sizing wing wall for a south facing  
3'x5' window, at 40 degrees north latitude.

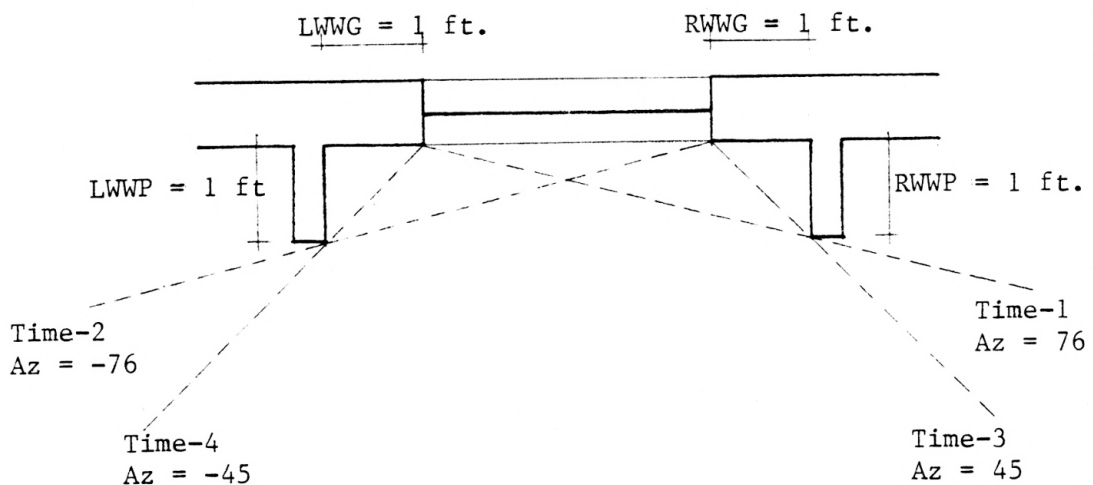
## Phase-II : Sizing Wing Wall

Input values -

Window Orientation : 0  
Month of Year For 100% Shade : 5  
Day of Month For 100% Shade : 21  
Beginning Hour of Day For 100% Shade (Time-1) : 9  
Ending Hour of Day For 100% Shade (Time-2) : 15  
Month of Year For 100% Sun : 11  
Day of Month For 100% Sun : 15  
Beginning Hour of Day For 100% Sun (Time-3) : 9  
Ending Hour of Day For 100% Sun (Time-4) : 15

Output -

Right Wing Wall Projection (RWWP) : 1.00 ft.  
Right Wing Wall Gap (RWWG) : 1.00 ft.  
Left Wing Wall Projection (LWWP) : 1.00 ft.  
Left Wing Wall Gap (LWWG) : 1.00 ft.



A summary of responses by Professor Dale Bryant  
Software Development Research, HTML, Inc, WA

Users

"...The program is advertised as simple. It does what it says it does. It does it badly, and with a minimum of confusion..."

"...The number of things which were done the program more useful than many others which they consider horizontal overviews."

"...It seems pretty clear from the user standpoint. The users all do exactly what they say they do. The analysis all work and update properly, and the analysis during the simulation all most perfect results."

Drawbacks:

"...The user interface is inconsistent. The main menu which it would have worked for all other input as well."

## F. User Response

"...The program has a very good design. It is very easy to use and very easy to learn. The ability to use the program makes the program of questions and answers very easy to learn..."

A summary of the user response is included here.

"...The program appears to have been written by someone with little programming experience. The program works, but it is hard to read, and it is very poorly organized. Many entries are far too long and are there is much more that is unnecessary..."

A summary of response by Professor Dale Bryant, currently CAD Software Development Manager, OCTAL Inc.,WA.

**Uses :**

"...The program is mathematically accurate...It does what it says it does. It does it quickly and with a minimum of confusion..."

"...The inclusion of sizing wing walls makes the program more versatile than many others which only consider horizontal overhangs..."

"...It seems pretty clean from the user standpoint. The inputs all do exactly what they say they do. The defaults all work and update properly, and the error messages during the solar simulation all make perfect sense..."

**Drawbacks :**

"...The user interface is inconsistent. The main menu structure would have worked for all other input as well..."

"...The program has no way of saving or retrieving data to and from computer files...The inability to save the design of a window makes the program of questionable usefulness in real-design situation..."

"...The program appears to have been written by someone with little programming experience...The program works, but it is hard to read, and relatively poorly organized. Many routines are far too long and, and there is much code that is unnecessary..."

Thanks for sending some time.  
Your response is greatly appreciated.

Name \_\_\_\_\_

Occupation \_\_\_\_\_

## UserResponse

---

SHADE

Computer program for sizing and analyzing fixed SHAding DEvices

Please indicate briefly your response for following items :  
(Use extra sheet of paper, if needed)

\* Usefulness :

\* Ease of Operation :

\* Bugs :

\* Adequacy of Documentation :

\* Enhancement :

Comments :

Thanks for spending some time.  
Your response is highly appreciated.

Name : \_\_\_\_\_

Date : \_\_\_\_\_

Occupation : \_\_\_\_\_



## **G. Program Listing**

SHADE is written using Turbo Pascal version 3.0 for IBM PCs and compatibles.

**Note**

The program listing and  
a compiled copy of  
SHADE  
is included in the  
Department of Architecture  
copy of this thesis report

# Bibliography

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- Brown, G. Z.. Sun, Wind and Light. John Wiley & Sons, 1985.
- Brown, G. Z., John S. Reynolds, M. Susan Ubbelchde, Susan Pledger. Upsidedown - The Salem Example Revisited. John Wiley & Sons, 1983.
- Bennett, R.. Sun Angles for Design. Robert Bennett, 1978.
- Foley, J. D. , A. Van Dam. Fundamentals of Interactive Computer Graphics. Addison-Wesly Publishing Company Inc., 1982.
- Givoni, B.. Man, Climate and Architecture. Van Nostrand Reinhold Company, 1981.
- Mazria, Edward. The Passive Solar Energy Book. Rodale Press, Emmaus, PA., 1979.
- Mitchell, William J., Robin S. Liggett, Thomas Kvan. The Art of Computer Graphics Programming. Van Nostrand Reinhold Company, New York, 1987.
- Olgyay, Victor. Design with Climate. Princeton University Press, Princeton, NJ., 1973.
- Olgyay, Aladar, Victor Olgyay. Solar Control and Shading Devices. Princeton University Press, Princeton, NJ., 1976.
- Stein Benjamin, John S. Reynolds, William J. McGuiness. Mechanical and Electrical Equipment for Buildings - Seventh Edition. John Wiley & Sons, 1986.
- "A Method of Estimating Monthly Average Solar Radiation on Shaded Receivers". D. M. Utzinger and S. A. Klien. Solar Energy, vol. 23, pp.369-378, Pergamon Press Ltd., 1979.
- "A simple Method for Sizing Overhangs". Michael Utzinger. Solar Age, July 1980.
- "Microcomputer Methods for Solar Design and Analysis". Building Applications and Regulatory Support Branch, U. S. Govt. Printing Office, 1981.

"Passive Solar Design Handbook", Vol. 2 of 2. Los Alamos Scientific Laboratory and Others, January 1980.

"Sun Angle Calculator". Libbey-Owens-Ford Company, 1974.

"Turbo Pascal", Reference Manual, Version 2.0. Borland International Inc., CA., 1983.

COMPUTER PROGRAM FOR SIZING AND ANALYZING  
FIXED **SHADING DEVICES**  
(**SHADE**)

by

VINOD S. CHATURVEDI

B.Arch., Bombay University, India, 1985

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the  
requirements for the degree

MASTER OF ARCHITECTURE

Department of Architecture  
College of Architecture and Design

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1990

1990-05-12  
CA-85  
SB-AD



# Abstract

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The computer program SHADE allows architects working in the preliminary design phase to size and evaluate the performance of fixed shading devices, such as horizontal overhangs or vertical wing walls, for any window at any latitude. It is also a useful tool for lay persons and students of architecture who are interested in learning more about Environmental Systems in Architecture. It is written using Turbo Pascal version 3.0 for IBM PCs or compatibles with color monitors.

It is developed to size and locate fixed horizontal overhang in Phase-I and vertical wing walls in Phase-II, for any window at any latitude. The limitation for sizing overhangs is that, they only can be sized correctly and practically for windows facing within 10 degrees east or west of due south. The edge effect of the overhang can be addressed by suitably sizing the overhang extension beyond the left or right edge of the window in Phase-III. The strongest and perhaps the most useful feature of SHADE is the shadow pattern simulation of the shading devices in Phase-IV. The performance of a shading device can be evaluated by viewing its shadow pattern at one hour intervals for the entire year, even at different window orientations. The percentage of window area in direct sunlight and shade is also displayed.

A hard copy of the graphics or text output can be easily printed at the stroke of a key anytime during the entire execution of the program.